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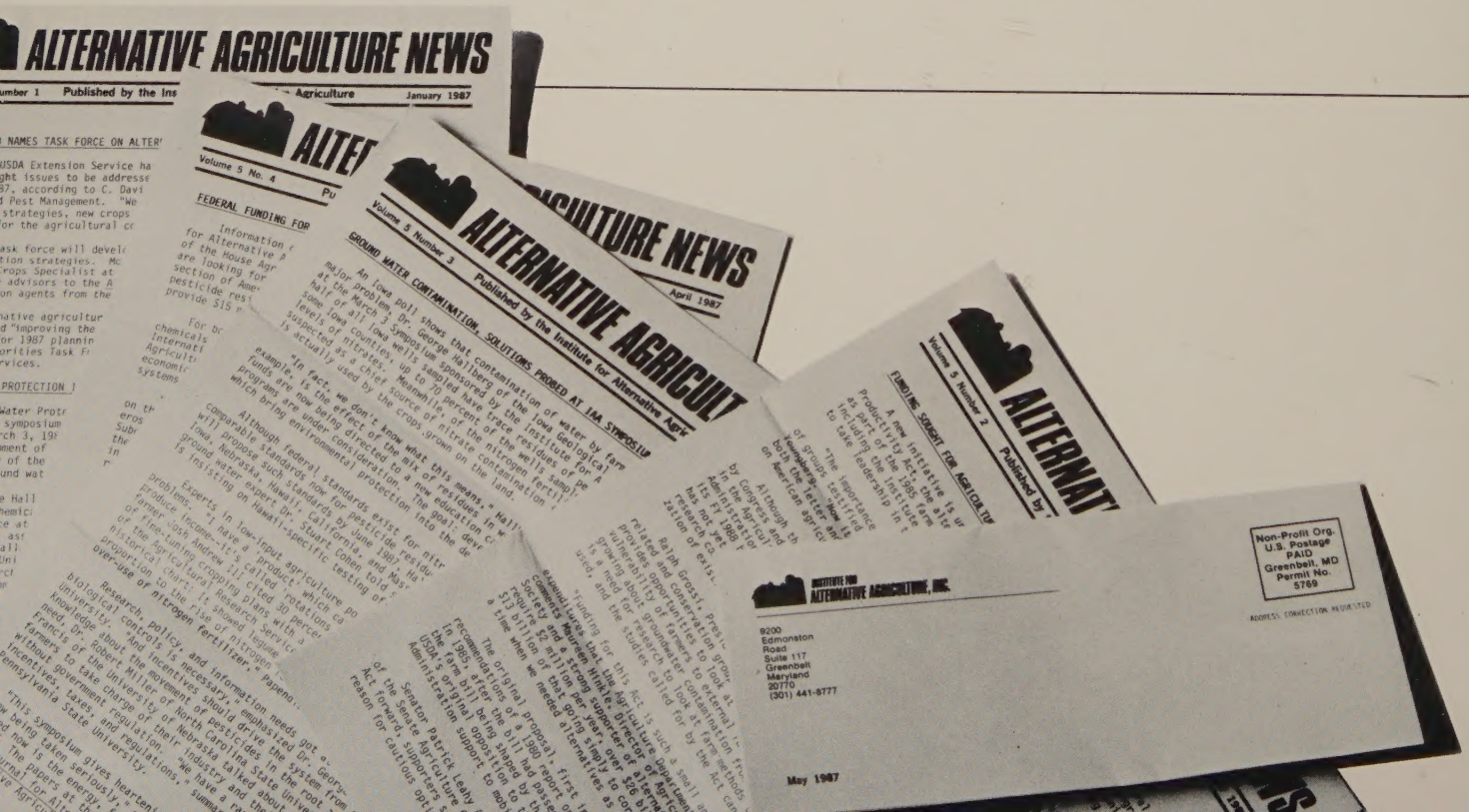
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Institute Information

The Institute for Alternative Agriculture is a nonprofit, tax-exempt research and education organization established in 1983 to encourage and facilitate the adoption of low-cost, resource-conserving and environmentally-sound farming methods. It works closely with producer groups, public research and education institutions, and government agencies in promoting a sustainable agriculture system.

Its programs include providing a national information clearinghouse, serving as a voice for sustainable agriculture in Washington, and developing and implementing research and educational outreach programs. It holds an annual scientific symposium and publishes a monthly newsletter.

The Institute is governed by a grass roots Board of Directors, which includes several commercial-scale organic farmers, and maintains a small professional staff. It is supported by memberships and donations and grants from foundations, corporations, and individuals.

Cover Photo

The cover photo illustrates the importance of organic amendments for improving the tilth, fertility, and productivity of marginal soils. Shown here, is the growth response of corn (*Zea mays* L.) on a marginal soil in Maryland, USA. The soil on the right was amended with 25 tons of sewage sludge compost per acre and no chemical fertilizer was applied. The soil on the left received the recommended rate of chemical fertilizer for optimum corn yields. Photo provided by J. F. Parr, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland.

OPINION

Beyond agroecology: Making sustainable agriculture part of a political agenda

Miguel A. Altieri

Although interest in sustainable agriculture has emerged worldwide, the motivation to pursue sustainable agricultural development varies according to the political, ecological, and socioeconomic climate of each region. In the industrialized countries (ICs) a major factor has been the need to deal with the consequences of technology-induced environmental degradation resulting from a sort of "development oversaturation." Conversely, in developing countries (LDCs), "development" has historically not reached a vast population of resource-poor farmers. Therefore, a driving force has been the need to match agricultural development with the needs of the rural poor.

In both cases, a central idea has been the development of an "appropriate technology" capable of translating productive potentials into sustainable livelihoods for all. Several agricultural research and development schemes have been suggested to reach this goal, among them agroecology.

In its various conceptions, agroecology has been proposed as a new scientific discipline that defines, classifies, and studies agricultural systems from an ecological and socioeconomic perspective. In addition to providing a methodology to diagnose the "health" of agricultural systems, agroecology is expected to delineate the ecological principles necessary to develop sustainable production systems.

Agroecology in the United States and the industrialized countries. In the 1980's several U.S., European, and Canadian universities and agricultural research centers have initiated research and education activities aimed at the development of land restorative, environmentally sound, economically viable, and socially acceptable agricultural systems. At the core of these projects is the desire to develop agricultural systems that sustain production in the long term without degrading the resource base. Thus the arsenal of options that potentially meet these goals includes a variety of low-input technologies that improve soil fertility and conservation, maximize recycling, enhance biological pest control, and diversify production. Intrinsic to these projects is the conviction that, as long as the proposed systems benefit the environment and are profitable, sustainability will eventually be achieved and all people wi benefit. Thus, sustainable agriculture technologies are seen a relatively neutral. Therefore, the question of which segment of society benefit from this technology is of little concern sinc it is assumed that what is good for the environment is goo for society at large. Such a position can prove problematic an dangerous for four main reasons:

a) If capital relations of production are not taken into accoun as a determinant of how and to whom technology is delivered technology (whether sustainable or not) will continue to b delivered preferentially to the class holding the capital an political power.

b) The focus on low-input technologies as a main componen of sustainable agricultural development will cause several bio technologies that clearly are not scale-neutral or capital-neutra to be proposed as viable options, thereby enhancing farmers dependence on the private sector.

c) If the issue of economics of scale is not addressed, and it is argued that sustainable production methods should not b restricted to small farmers, corporate and large-scale farmer will rapidly shift to alternative methods because there is a goo prospect for monetary gain (i.e., low inputs reduce costs o production). This shift potentially will displace some sma farmers committed to sustainable agriculture not only becaus of financial reasons, but because of ecological and moral one As competition increases, more small farmers will shift to spe cialty crops oriented to elite markets as a way to exploit eco nomic windows in order to survive in the capitalist-oriente economy. Such trends are already occurring in California.

d) If only environmental quality is emphasized, and if th fact that large-scale farmers are at least not "polluting" an more is considered sufficient, other factors that make a su tainable agriculture socially just and humane can be oversha dowed. Within this framework, the fact that certain organi farmers do not provide proper wages and living conditions t their farm workers can easily be "overlooked." This is und sirable and obviously can complicate and even polarize the labo issues within the organic industry, as in the grape boycott le by the United Farm Workers' Union.

It, therefore, is crucial that scientists involved in the searc

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for sustainable agricultural technologies be concerned about who will ultimately benefit from them. This requires them to recognize that political determinants enter when basic scientific questions are asked, and not only when technologies are delivered to society. Thus what is produced, how it is produced, and for whom it is produced are key questions that need to be addressed if a socially equitable agriculture is to emerge. When such questions are examined, issues of land tenure, labor, appropriate technology, public health, and research policy unavoidably arise. Examination of these questions should proceed even if it means recognizing that political systems other than the capitalist model might represent the best hope to assault the structural basis underlying the environmental crisis of modern agriculture.

Agroecology in the developing countries. In the LDCs, history shows that increases in agricultural productivity, whether through sustainable technologies or not, cannot solve the problem of rural poverty. Thus a major dilemma facing agroecologists in LDCs is how to further increase agricultural productivity in a way that allows the rural poor to benefit significantly. The challenge, however, is to realize that this is not really possible without improving the access of peasants to land, water, other natural resources, as well as to equitable credit, markets, and appropriate technologies. Only political change derived from progressive government or strong community-based actions can secure farmers' control over the institutions that govern access to resources and inputs. Agroecology can only hope to provide the ecological basis to manage the resources once available to the rural poor. In other words, as an agricultural development approach, agroecology cannot confront the structural and economic factors that underlie rural poverty. As emphasized above, this will require a much broader development approach that, among other things, effectively addresses the question of social organization of the peasantry.

Therefore, more than creating or transferring new technology, a fundamental idea of agroecology should be to encourage the emergence of an attitude towards the technological process that allows farmers to discriminate, select, and adopt new technologies, and also to validate those that originate within their own social group. In Latin America several non-government organizations have taken this approach, creating programs that emphasize research, education, technical assistance, and credit provision aimed at the development of peasant agriculture. Many of these groups have demonstrated a special ability to understand the specific and differentiated nature of small-farm production and have promoted some successful experiences in generation and transfer of peasant technology.

These groups recognize, however, that ultimate sustainability will be reached as farmers increase their access to land, resources, and a suitable technology that allows them to ecologically manage these resources and also become socially organized to secure governance of resources, equity of access to markets for inputs and products, and to income derived from harvests.

Conclusions. Regardless of whether the worldwide problem of sustainability of agriculture gets addressed through a political agenda aimed at modifying governance of and access to resources, the question of technology development will remain a vital one. In this context, agroecology can be a useful tool to guide such a process.

Undoubtedly, agroecology has allowed us to better understand in an integrated manner the various factors that govern agricultural productivity and to develop new technological avenues to overcome these factors in a more environmentally sound manner. However, by perceiving the problem of sustainability solely as a problem of sustaining production without degrading the resource base, most agroecological approaches are restricted in their ability to understand and address the root causes that drive agricultural systems to become nonsustainable. Clearly, new sustainable agroecosystems cannot be implemented without modifying the socioeconomic determinants that govern what is produced, how it is produced, and for whom it is produced. The technological issues addressed by agroecology must assume their corresponding role within a political agenda that incorporates social and economic dimensions in its development strategy. Only policies and actions derived from the implementation of such strategy can confront the structural and economic factors that underlie the agricultural-environmental crisis in the ICs and rural poverty in the LDCs.

Agroecologists must continue their multidisciplinary research and training efforts so that our understanding of the complex factors governing agricultural sustainability expands. But this scientific understanding must be guided by a broader understanding: that of the relationship between political institutions, social classes, and the scientific community. Continuation of a purely technological focus, even if the promoted technologies are "sustainable," will further obscure the recognition of the factors that make agriculture unsustainable in the first place.

Guidelines for Developing University Sustainable Agriculture Programs, from the Wisconsin Rural Development Center (WRDC), identifies central characteristics of successful programs. It is designed both to guide university groups and to provide interested citizens with a tool to judge such programs. Copies of the 32-page guide are $5 from the WRDC, P.O. Box 504, Black Earth, WI 53515-0504.

Comparison of soil properties as influenced by organic and conventional farming systems

John P. Reganold

Abstract. *This paper summarizes data from previous and current studies on two adjacent farms, one organically managed and the other conventionally managed, in the Palouse region of eastern Washington. The 320-hectare organic farm has been managed without the use of commercial fertilizers and only limited use of pesticides since the farm was first plowed in 1909. The 525-hectare conventional farm, first cultivated in 1908, began receiving recommended rates of commercial fertilizers and pesticides in 1948 and the early 1950's, respectively. The organically-farmed Naff silt loam soil had significantly higher organic matter, cation exchange capacity, total nitrogen, extractable potassium, water content, pH, polysaccharide content, enzyme levels, and microbial biomass than did the conventionally-farmed Naff soil. Also, the organically-farmed soil had significantly lower modulus of rupture, more granular structure, less hard and more friable consistence, and 16 centimeters more topsoil. This topsoil difference between farms was attributed to significantly greater erosion on the conventionally-farmed soil between 1948 and 1985. The difference in erosion rates between farms was most probably due to their different crop rotation systems; i.e., only the organic farm included a green manure crop in its rotation, and it had different tillage practices. These studies indicate that, in the long-term, the organic farming system was more effective than the conventional farming system in maintaining the tilth and productivity of the Naff soil and in reducing its loss to erosion.*

Key words: organic matter, cation exchange capacity, water content, enzyme levels, microbial biomass, erosion

Introduction

The USDA definition (1980) considers organic farming to be a system that avoids or excludes the use of synthetic fertilizers and pesticides and relies upon practices such as crop rotations, use of animal and green manures, and aspects of biological pest control. Conventional farming is a system that is heavily dependent on the use of synthetic fertilizers and pesticides. Researchers have shown that organic farming systems have the potential to reduce some of the negative impacts of conventional agriculture on the environment. For example, the reduction or non-use of manufactured chemicals with organic farming systems has been shown to decrease the environmental hazards and possible adverse effects on wildlife (Dahlgren, 1967; Klaas, 1982; Papendick et al., 1986). In addition, the increased use of synthetic fertilizers, insecticides, fungicides, herbicides, and antibiotics in modern conventional agriculture has increased the probability of people being exposed to toxic hazards (Clancy, 1986; Hallberg, 1987).

Few studies have been done that actually compare the effects of organic farming to conventional farming on properties of the same soil type(s), such that all soil-forming factors, except management, are equal. Some of these factors include microclimate, microtopography, natural vegetation, and parent material (Jenny, 1941; Buol et al 1980). Although conducting such re search may seem relatively easy, findin experimental sites on working farms where soil-forming factors are invarian and both farming systems are in-place is difficult and yet necessary to validat the researchers' data (Daniels et a 1987). To insure uniformity of these soil forming factors, such that there is littl to no within-experimental site soil var iability, the organic and conventiona fields should be adjacent to one anothe and plots from the organic field shoul be in close proximity to those from th conventional field. The validity of such research is based on the assumption tha all soil properties within the experimen tal site were similar before first bein cultivated or before the two manage ment systems begin to differ. Thus, an change in soil properties at some poin in time after the advent of these tw systems will be due to differences in th management systems.

This paper summarizes soil biological chemical, and physical data from pre vious studies (i.e., Weilgart Patten 1982; Bolton, Jr. et al., 1985; Reganol et al., 1987) and current investigation of this nature, which were conducted o the same study area of two such farm in the Palouse region of Washingto State. In addition, differences in wate and tillage erosion and crop rotation sys tems between farms are discussed. Th objective of each of these studies was t determine the long-term effects of or ganic and conventional farming on se lected soil properties of Naff silt loam

Study area and methods

The two farms were situated 30 kil ometers south of Spokane, Washington in the northern part of the productiv

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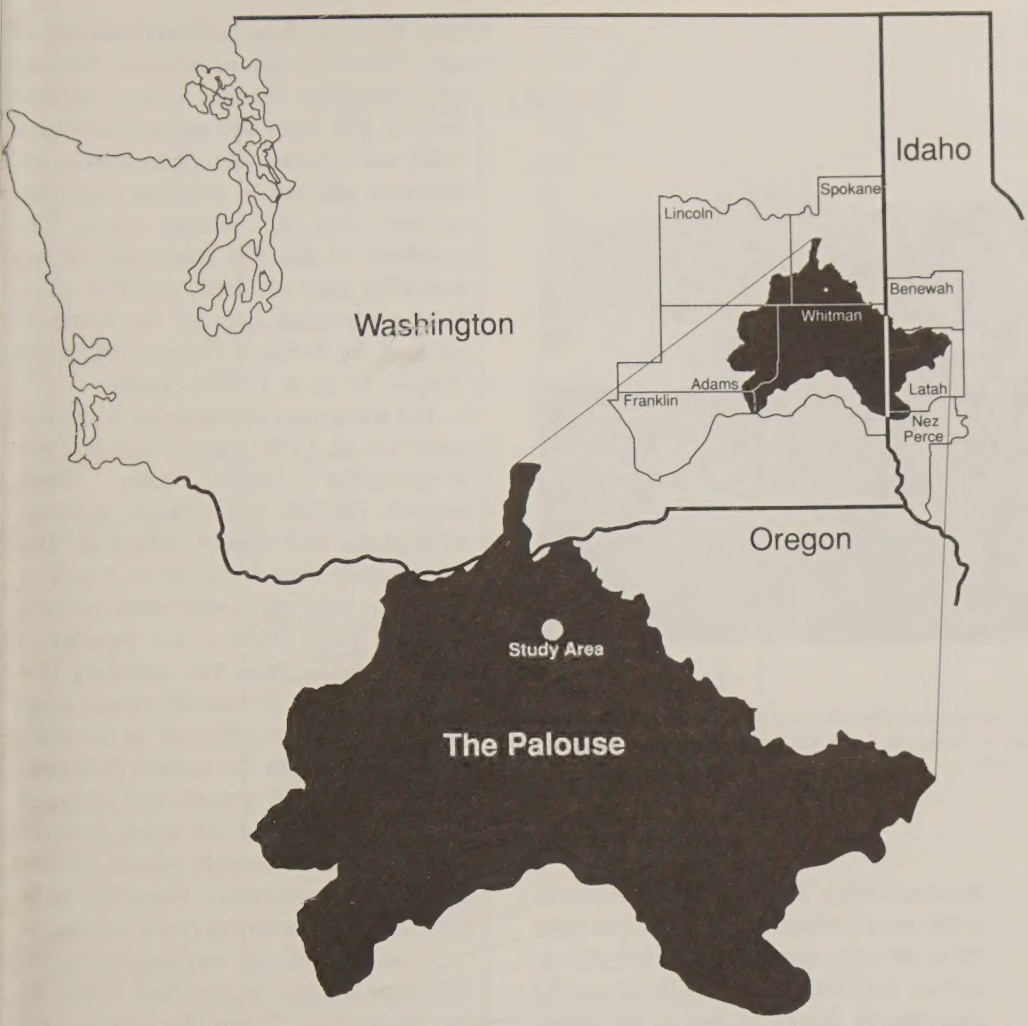

Figure 1. The study area is located in the Palouse area of Spokane County, Washington.

dryland winter wheat/spring pea area called the Palouse (Figure 1). The 320-hectare organically-managed farm (Figure 2) was identified in the USDA report (1980) on organic farming as having been managed without the use of inorganic fertilizers and only limited use of pesticides since the farm was first plowed in 1909 (Table 1). Pesticides, which were first applied in the mid-1960s, were used almost exclusively on spring peas *(Pisum sativum)* and in ditches and draws. The organic farm relied upon green manure crops, crop rotations, and native soil fertility for plant nutrients. In general, the organic farm used a three-year crop rotation of winter wheat *(Triticum aestivum)*-spring pea *(Pisum sativum)*-green manure of Austrian winter pea (*Pisum sativum* spp. *arvense* L. Poir) or an alfalfa *(Medicago sativa)*-intermediate wheatgrass *(Agropyron trachyeaulum)* mixture. The Austrian winter pea (a legume) was grown one in every six to eight years and the alfalfa-wheatgrass mixture was grown two consecutive years in every eight to ten; thus, a legume-based green manure crop was used on average every third year in the crop rotation. The alfalfa-wheatgrass mixture was not fed to farm animals or sold, but completely turned under in the soil. Summer fallow was used once in every six to nine years for water conservation and weed control (Table 1).

The adjoining 525-hectare conventional farm was first cultivated in 1908 but did not begin receiving recommended rates of fertilizers and pesticides until 1948 and the early 1950s, respectively. Winter wheat received N, P, and S applications at 96, 34, and 16 kg ha-1, respectively; spring peas received no fertilizer. The conventional farm generally used a crop rotation of winter wheat *(Triticum aestivum)*-spring pea *(Pisum sativum)*. Summer fallow was used about every sixth year for water conservation in dry years, and spring barley (*Hordeum vulgare* L.) replaced spring pea about every tenth year. It is assumed that the two farms were managed the same prior to 1948, including the same crop rotations and tillage practices. Since 1948, both farmers have used the moldboard plow (to a soil depth of 15 to 20 centimeters); however, only the organic farmer has regularly used a chisel plow (to a soil depth of 20 to 25 centimeters), while only the conventional farmer has regularly used a disc.

The study area was located at the juncture of the two adjoining farms (midway on an approximate 200 meter east facing slope), such that all soil forming factors, except management, as described by Jenny (1941) in the following equation were equal:

$$s = f(mngt)_{cl,\ o,\ r,\ p,\ t\ \ldots}$$

where s = soil properties, f = "function of", mngt = farm management systems, cl = climate, o = natural vegetation, r = relief, p = parent material, and t = time. Although the natural vegetation ("o") was the same on both farms dur-

Table 1. General Farm Characteristics

Characteristic	Organic Farm	Conventional Farm
Size (ha)	320	525
First Cultivation	1909	1908
First Commercial Fertilization	—	1948
Fertilizer	green manure legume	N, P, S
First Pesticide Application	mid-1960s	early 1950s
Pesticide Use	limited	recommended
Crop Varieties	similar	similar
Representative Crop Rotation	winter wheat-spring pea-Aust. winter pea-winter wheat-spring pea-alfalfa/grass-alfalfa/grass-summer fallow	winter wheat-spring pea-winter wheat-spring pea-winter wheat-summer fallow

Figure 2. The juncture in the study area between the conventional (far left) and organic (right) farms. The organic farm has been managed without the use of inorganic fertilizers and only limited use of pesticides since the farm was broken out of sod in 1909.

ing the time of soil formation and up to the time of farming, the two farm management systems have had different crop rotations since 1948 and thus different biotic influences (e.g., green manure crops in only one system) which can cause differences in soil properties ("s"). However, these differences are attributed to the different farm management systems ("mngt").

The slope of the study area was mostly 4.0 degrees (7 percent), ranging from 2.8 to 6.3 degrees (5 to 11 percent), in two directions for each farm field: (1) 4.0 degrees downhill to the east for both farms as well as (2) 4.0 degrees downhill south for the organic farm and 4.0 degrees downhill north for the conventional farm (Figure 3). Since the soils were sampled so close to the summit (the boundary line between farms), differences in aspect were considered insignificant. The study area was made up of Naff silt loam, a fine-silty, mixed, mesic Ultic Argixeroll. The dark-colored, well-drained Naff soil formed under perennial grassland in deep deposits of loess mixed with some thin layers of volcanic ash (Soil Conservation Service and Washington Agricultural Experiment Station, 1968). Typically, Naff soils have a silt loam surface A1 horizon less than 20 to 46 centimeters thick, overlying an A2 or AB horizon (typically about 23 centimeters thick) of heavy silt loam. (Although the Naff soils on these farms had an Ap horizon (plower layer) and an A2 horizon instead of an A1 and then an A3 instead of A2 horizon, the Ap horizon is not differentiated as the top part of the A1 horizon in this study.) The next layer is a strong, silty clay loam Bt or argillic B horizon (a layer of clay accumulation that is significantly denser than the layer(s) above) extending to a depth of 150 centimeters.

Although the general study area (Figure 3) was the same for the different investigations, the plots for the different studies were not in the exact same locations. Weilgart Patten (1982) used four plots; Bolton, Jr. et al. (1985) used eight plots; Reganold et al. (1987) used four plots and a 55-meter pair of transects. Soil samples were collected in the Fall 1980 and Spring 1981 (Weilgart Patten, 1982), Summer and Fall 1981 and Spring 1982 (Bolton, Jr. et al., 1985), and Summer 1985 (Reganold et al., 1987). The Weilgart Patten and Bolton, Jr. et al. data included analyses o the following soil properties: Enzym and microbial biomass assays, organ matter, pH, total and mineral nitroge total and extractable phosphorus, e tractable potassium, calcium, and ma nesium, and rill erosion rates. Th numbers of samples analyzed, the la and field methods used, and the stati tical procedures run can be found i each of the Weilgart Patten (1982) an Bolton, Jr. et al. (1985) studies.

The soil properties reported in the R ganold et al. (1987) study included p lysaccharide content, color, wat content, texture, bulk density, modulu of rupture, and topsoil thickness. Th initial study area consisted of a pair transects, with ten sample points in eac transect. Each transect was parallel t and 4.5 meters from the boundary lin (between the farms) and 55 meters lon Soil samples were collected in the sum mer of 1985 from the surface 0-10 cen timeters for all 20 samples and analyze for bulk density and soil water conten At the same 20 sample points, deepe soil cores (7 centimeter diameter) to a least 100 centimeters in depth were ana lyzed in the field for soil texture, colo thickness of A1 horizon and depth t the Bt horizon. From the texture an color changes evident in the soil co profiles, thicknesses of the surface ho rizons to the underlying argillic (Bt) ho rizons were determined. A *t*-test wa used to compare the bulk densitie water contents, thickness of the A1 ho rizons, and depths to the Bt horizon between the two farms.

The study area also consisted of fou plots (6.1 X 9.1 meters), two on eac side of and 6.1 meters away from th boundary line between the farm Twenty surface soil samples (0-10 ce timeters depth) were collected from grid pattern superimposed on each of th four plots for a total of 80 samples. The samples were analysed for modulus rupture using the Reeve method (196 and polysaccharide content according the anthrone method proposed by Brin et al. (1960) and modified by Mettin and Rayburn (1983). Statistical com parisons of the results were made usin ANOVA.

New analyses in this paper inclu

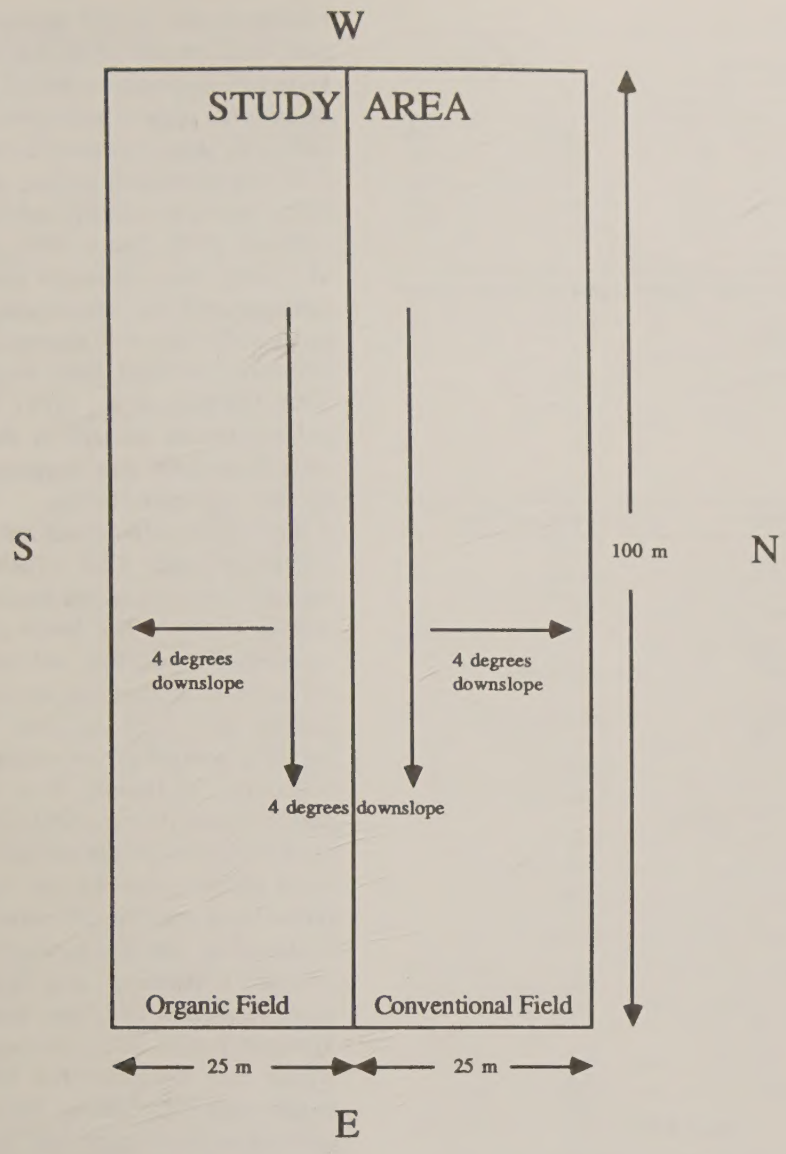

Figure 3. Diagram of the study area at the juncture of the two adjoining farms.

cation exchange capacity (CEC), extractable P, K, Ca, and Mg, particle-size, structure, consistence, and estimates of water erosion using the same plots and soil samples from Reganold et al. (1987) and using ANOVA to make statistical comparisons. CEC and extractable P, K, Ca, and Mg were measured using the Na saturation method (United States Salinity Laboratory Staff, 1954) and NaOAc extractable tests (Peach and English, 1944), respectively. Particle-size was determined using the hydrometer method (Bouyoucos, 1951; Day, 1965). Soil structure and consistence were determined in the field using standard Soil Conservation Service procedures (Soil Survey Staff, 1951). Water erosion estimates were based on the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978).

Results and discussion

Biological and chemical properties

Bolton, Jr. et al. (1985) found that the organically-farmed soil had significantly higher levels of urease, phosphatase and dehydrogenase activity at three different sampling dates than did the conventionally-farmed soil (Table 2). Both farm fields were under the same crops or residues for all three sampling dates, i.e., under maturing winter wheat on 21 July 1981, after plowdown of winter wheat straw and stubble on 11 November 1981, and under a crop of spring peas on 11 May 1982. Soil enzymes originate from animal, plant and microbial sources, but they are assumed to be derived primarily from soil microorganisms (Bolton, Jr. et al., 1985). If this is true, then the enzyme assay results indicate that microbial activity was higher under the organic management system. In addition, the organically-farmed soil had significantly higher levels of microbial biomass in the July and November samples and significantly higher N flush levels (which also represents a measure of biomass) at all three sampling dates (Table 2). The biomass and N flush data indicate that the organically-farmed soil had a larger amount of soil microorganisms present (Bolton, Jr. et al., 1985).

Table 3 lists general soil biological and chemical analyses from surface and subsurface soil samples gathered between 1981 and 1985. Most properties are represented by data from two different dates to illustrate their consistency over time. Surface soil organic matter from all three sampling dates was 25 to almost 60 percent higher on the organically-farmed soil than on the conventionally-farmed soil (Table 3). Subsurface (15-30 centimeters) soil organic matter was also significantly higher (29 percent) on the organic farm. These results support the conclusion that organic farmers can, and generally do, achieve higher organic matter levels in their soils than do conventional farmers (Oelhaf, 1978; Lockertz et al., 1981).

Organic matter has a profound impact on soil quality; it encourages granulation, increases water storage, nutrient supply, and soil organism activity, and improves soil fertility and productivity (Allison, 1973; Russell, 1973; Johnston, 1986). Larger amounts of decomposing organic residues keep the soil in better physical condition, increasing water infiltration and improving its supply to the plant (Horner et al., 1944; Tisdale et al., 1985). Thus, plants are better able to withstand periods of drought; also, less

Table 2. Soil Microbiological Properties (Bolton, Jr. et al, 1985)

Soil Property (Surface Soil, 0-15 cm)	July 1981		Nov. 1981		May 1982	
	Org.	Conv.	Org.	Conv.	Org.	Conv.
Urease[a]	2.5**	1.7	2.8**	1.7	3.0**	1.6
Phosphatase[b]	3.5**	3.0	2.2**	1.8	2.1**	1.5
Dehydrogenase[c]	8.6**	5.9	9.6**	5.7	7.3**	4.3
Biomass[d]	314**	248	237**	136	142	124
N flush (u g N g^{-1})	14.5**	7.2	12.0**	5.3	11.2**	2.5

[a] 10^{-2} u mol NH_4^+-N g^{-1} min^{-1}; [b] 10^{-2} u mol p-nitrophenol g^{-1} min^{-1}; [c] 10^{-5} u mol triphenylformazan g^{-1} min^{-1}; [d] ug C g^{-1}.
*,** Statistically significant at the 0.05 and 0.01 levels, respectively

Table 3. Soil Biological and Chemical Properties

Soil Property	Organic Farm	Conventional Farm
Organic Matter (0-10 cm)[a]	2.7%**	1.7%
Organic Matter (0-15 cm)[b]	1.9%*	1.5%
Organic Matter (0-15 cm)[c]	2.5%[+]	2.0%
Organic Matter (15-30 cm)[c]	1.8%	1.4%
Polysaccharide Content (0-10 cm)[d]	1.13 mg/ml*	1.00 mg/ml
C.E.C. (0-10 cm)[a]	17.3 cmol/kg*	15.6 cmol/kg
pH (0-15 cm)[b]	56.9*	5.7
pH (0-15 cm)[c]	6.1	6.0
	(mg/kg)	
Total N (0-15 cm)[b]	1179*	1066
Total N (0-15 cm)[c]	1162	1029
Total N (15-30 cm)[c]	910	758
Mineral N (0-15 cm)[b]	11.5	28.5**
Total P (0-15 cm)[c]	598	600
Total P (15-30 cm)[c]	546	530
Ext. P (0-10 cm)[a]	5.5	5.3
Ext. P (0-15 cm)[c]	8.9	6.6
Ext. P (15-30 cm)[c]	6.2[+]	2.9
	(cmol/kg)	
Ext. K (0-10 cm)[a]	1.2**	0.7
Ext. K (0-15 cm)[c]	0.9*	0.5
Ext. K (15-30 cm)[c]	0.6	0.4
Ext. Ca (0-10 cm)[a]	8.2	8.1
Ext. Ca (0-15 cm)[c]	8.1	8.6
Ext. Mg (0-10 cm)[a]	2.3	2.5
Ext. Mg (0-15 cm)[c]	2.8	3.4

[a] Summer 1985 samples (Reganold, unpublished); [b] Average of Summer and Fall 1981 and Spring 1982 samples (Bolton, Jr. et al., 1985); [c] Average of Fall 1980 and Spring 1981 samples (Weilgart Patten, 1982); [d] Summer 1985 samples (Reganold et al., 1987); [e] Fall 1980 samples (Weilgart Patten, 1982).
[+],*,** Statistically significant at the 0.10, 0.05, and 0.01 levels, respectively

water runs off and erosion is reduced. From available data on dryland farms in the Midwest, Poincelot (1986) showed that yields on organic farms during drought are comparable to or slightly better than those on conventional farms. He concluded that organic farms have an advantage during drought because of their emphasis on replacing or increasing soil organic matter.

Soil from the organically-farmed field had significantly higher polysaccharide content than soil from the conventionally-farmed field (Table 3). Polysaccharides, some of which are produced by soil microorganisms, serve as active binding agents in soil aggregate form tion, and are one of several factors i volved in aggregate stability, the othe being other organic polymers, microbi cells, clay skins, inorganic cements (e.g iron and aluminum oxides, amorphou silica, and carbonates), and plant roo (Allison, 1968; Lynch, 1981; Molope al., 1987). Since research studies hav substantiated the importance of pol saccharide content to aggregate stabili (Martin, 1945 and 1946; Action et a 1963; Dormaar et al., 1979), the high polysaccharide content in the organ cally-farmed soil may suggest its havi greater aggregate stability.

The organically-farmed soil had a si nificantly higher CEC (Table 3), pr sumably because of the higher organ matter content. The lower pH in th conventionally-farmed soil probably r sulted from ammonium fertilizer appl cations and from a lower bufferi capacity because of less organic matte Although the Bolton, Jr et al. (198 and Weilgart Patten (1982) data for t tal Kjeldahl N in the surface soil ind cated higher values for the organicall farmed soil, only the difference found b Bolton et al. was statistically significa (Table 3). However, it is likely that more replicates had been made in th Weilgart Patten study, then significan would have been detected. Mineral n trogen was significantly higher in th conventionally-farmed soil because the addition of chemical nitrogen ferti izer.

Total P in the top 30 centimeters soil and extractable P (NaOAc metho in the top 15 centimeters of soil we not significantly different betwe farms, but extractable P was signi cantly higher ($P < .10$) in the subsu face in the organically-farmed s (Table 3). Extractable P provides an i dex of available soil P for plants (Blac 1968). Levels measured were about a erage for soils from Spokane Coun tested by the Washington State Unive sity Soil Testing Lab (Weilgart Patte 1982). Lockeretz et al. (1981) found e tractable P (Bray P1) to be higher ($< .10$) and extractable P (Bray P2) be no different on midwestern conve tional farms compared to organic farm

Extractable K was significantly high

Table 4. Soil Physical Properties

Soil Property (Surface Soil, 0-10 cm, except where noted)	Organic Farm	Conventional Farm
Surface Color (dry)[a]	10YR 4/2	10YR 5/2, 5/3
Water Content (%)[a]	15.5**	9.0
Surface (A1) Texture[a]	silt loam	silt loam
Subsurface (A2) Texture[b]	silt loam	silt loam
Subsoil (Bt) Texture[a]	silty clay loam	silty clay loam
Bulk Density ($Mg\ m^{-3}$)[a]	1.0	1.0
Structure[b]	granular	subangular blocky parting to granular
Consistence (dry)[b]	slightly hard	hard to very hard
Consistence (moist)[b]	friable	firm
Consistence (wet)[b]	slightly sticky, slightly plastic	slightly sticky, slightly plastic
Modulus of Rupture (MPa)[a]	1.6×10^{-2}	2.0×10^{-2}*
Surface (A1) Horizon Thickness (cm)[a]	39.8*	36.7
Depth to Bt Horizon (cm)[a]	55.6**	39.8
Rill Erosion ($Mg\ ha^{-1}$)[c]	8.3	32.4
USLE Water Erosion ($Mg\ ha^{-1}$)[b]	7.8	20.4

[a] Summer 1985 samples (Reganold et al., 1987); [b] Summer 1985 samples (Reganold, unpublished); [c] Spring 1981 (Weilgart Patten, 1982).
*,** Statistically significant at the 0.05 and 0.01 levels, respectively

in the organically-farmed soil but extractable Ca and Mg concentrations were not significantly different. Extractable K levels were above average for the organically-farmed soil and about average for the conventionally-farmed soil compared to levels expected for Spokane County (Weilgart Patten, 1982). The higher extractable K in the organically-farmed soil is probably indirectly related to its higher organic matter content. A higher proportion of this soil's CEC will be due to organic matter compared to the conventionally-farmed soil's CEC, and organic matter exchange sites do not fix K (keeping it available to the plant) as do illite-type clay minerals (which are predominant in Palouse soils). Since Ca and Mg are not fixed by clay minerals (or organic matter) and are readily extractable on mineral (and organic) exchange sites, their concentrations were not significantly affected by the difference in organic matter contents between farms (James B. Harsh, Washington State University, 1988, personal communication). Concentrations of N and P are maintained on the conventional farm by additions of commercial fertilizer.

Physical properties

The surface layer of the organically-farmed soil was darker (10YR 4/2 or dark grayish brown) than that of the conventionally-farmed soil (10YR 5/2 or grayish brown, and 10YR 5/3 or brown) due to the significantly higher organic matter levels in the organically-farmed soil (Table 4). Summer water contents were significantly higher in the organically-farmed soil, which may also be attributed to its having higher organic matter levels. Soils on both farms had silt loam surface (A1) texture, silt loam subsurface (A2) texture, and silty clay loam subsoil (Bt) texture (Table 4). Bulk densities of the organically- and conventionally-farmed soils were not significantly different.

The surface soil structures for the two soils were distinctly different, with that of the organically-farmed soil being granular and that of the conventionally-farmed soil being subangular blocky parting to granular (Table 4). A well-granulated soil has the best structure for most ordinary crop plants (Brady, 1984); it allows free percolation of excess moisture and at the same time enables roots to grow freely in the pore space between the soil aggregates (FitzPatrick, 1986). The major agency in the encouragement of granular type aggregate formation in surface soil horizons is organic matter (Brady, 1984). The decay of plant roots, the disruptive action of their movement, the chemical properties of humus and clay, and the slime and other viscous microbial products (e.g., polysaccharides) also encourage granular aggregate development and stabilization. Other factors affecting the genesis of granules are wetting and drying, freezing and thawing, and soil tillage.

Soil consistence in the dry and moist states was also distinctly different between the two soils. Soil consistence is a term used to describe the resistance of a soil at various moisture contents to mechanical stresses or manipulations and is commonly measured by feeling and manipulating the soil by hand (Brady, 1984). Although consistence and structure are interrelated, structure deals with the shape, size, and distinctness of natural soil aggregates that result from variations in the force of attraction within a soil mass, whereas consistence deals with the strength and nature of such forces themselves (Soil Survey Staff, 1951.) Consistence is relevant to tillage and traffic by farm machinery; if it is too dry and hard, undue strain will be placed on the implements (FitzPatrick, 1986).

The dry consistence of the organically-farmed soil was slightly hard (i.e., easily broken between thumb and forefinger), whereas that of the conventionally-farmed soil was hard (i.e., difficult to break between thumb and forefinger) to very hard (i.e., cannot be broken between thumb and forefinger) (Table 4). The moist consistence of the organically-farmed soil was friable (i.e., crushes easily under gentle to moderate pressure between thumb and forefinger), whereas that of the conventionally-farmed soil was firm (i.e., crushes under moderate pressure between thumb and forefinger but resistance is distinctly noticeable). There were no distinct differences between wet consistences (i.e., degree of stickiness and plasticity). Since soil consistence is a measure of the ease with which a soil can be reshaped or ruptured, mechanical tillage should be easier on the organically-farmed soil because it is less hard (when dry) and more friable (when moist).

The organically-farmed soil had a significantly lower modulus of rupture (Table 4), an index related to the hardness of surface crusting. In general, the lower the modulus of rupture, the easier it is for seedlings to emerge. The modulus of rupture test was designed to imitate the process by which seedlings force their

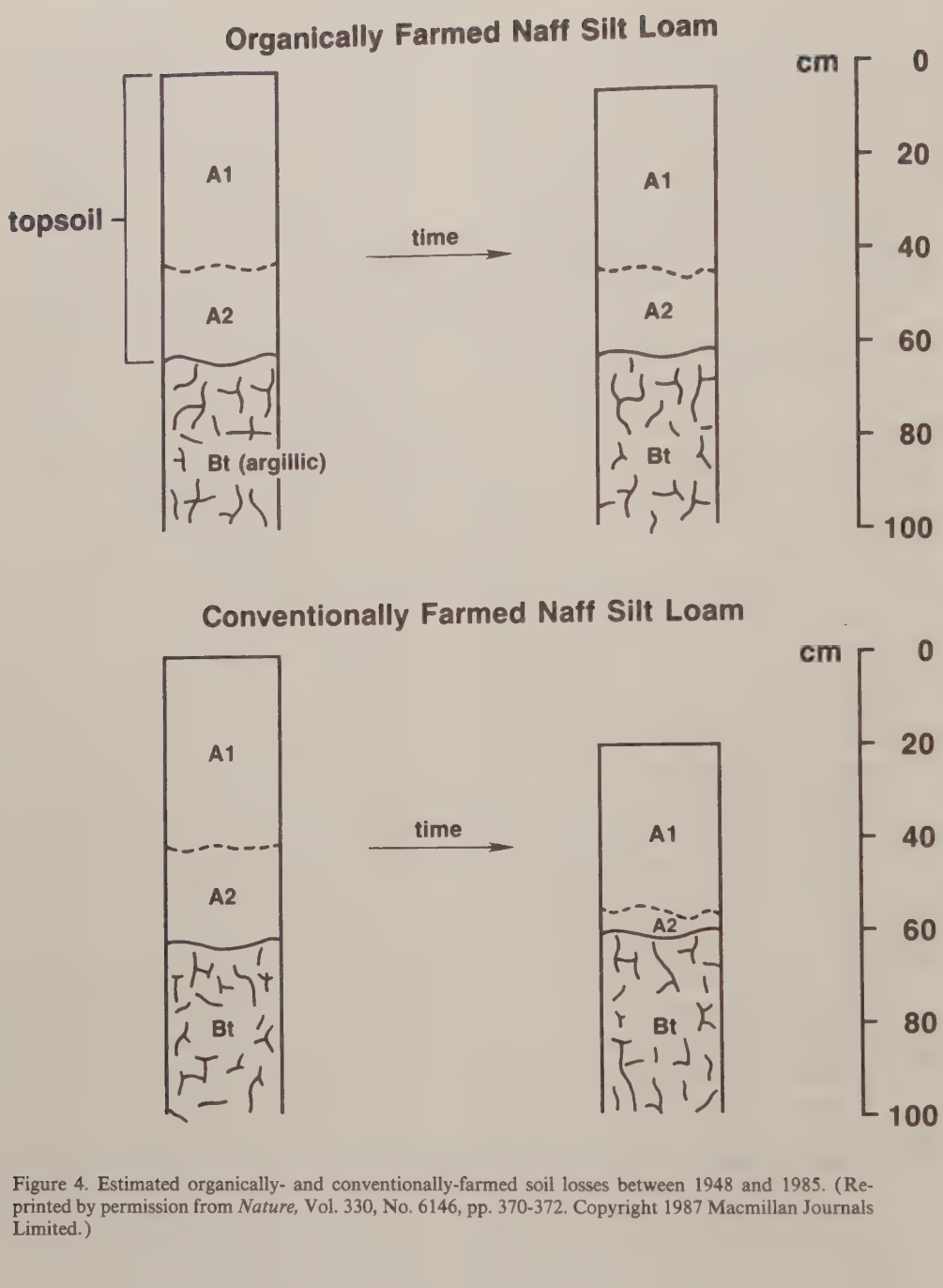

Figure 4. Estimated organically- and conventionally-farmed soil losses between 1948 and 1985. (Reprinted by permission from *Nature,* Vol. 330, No. 6146, pp. 370-372. Copyright 1987 Macmillan Journals Limited.)

way upward by penetrating and rupturing surface soil crust (Hillel, 1982). Soil crusting occurs when surface aggregates collapse and slake during wetting and then form a slick dispersed layer; upon drying, this dispersed layer shrinks to become a dense, hard crust which impedes seedling emergence by its hardness and tears seedling roots as it cracks. The significantly lower modulus of rupture for the organically-farmed soil is probably due to its higher organic matter content.

Because of its more granular structure, more friable and less hard consistence, lower modulus of rupture, and higher organic matter content, the organically-farmed soil had better soil tilth than did the conventionally-farmed soil. Tilth is the physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its impedence to seedling emergence and root penetration (Brady, 1984; Hausenbuiller, 1985). The ideal tilth desired by farmers is generally for a soil having medium texture (e.g., loam or silt loam), crumb or granular structure, friable consistence, and a balanc of macro- and micropores (FitzPatrick 1986).

The surface horizon of the organically-farmed soil was significantl thicker (by 3 centimeters) than the surface horizon of the conventionally farmed soil (Table 4). Topsoil thickness represented by the depth of the soil layers (A1 and A2 horizons) to the subso argillic (Bt) horizon, was almost 16 centimeters greater in the organically farmed than in the conventionally farmed soil. These differences, especiall the large difference in topsoil depth, ar attributed to significantly greater so losses due to erosion on the conventionally-farmed soil between 1948 and 198

Soil erosion

Erosion over time causes a continu thinning of the soil. Not only is the surface horizon thickness reduced, bu more significantly, the subsoil layer((in this case, an argillic layer) is brough nearer to the surface (Figure 4). Despi the higher erosion rate on the conventionally-farmed soil, its surface (A1) h rizon thickness was only slightly thinn (by 3 centimeters) than that of the o ganically-managed soil. This was due its continual mixing with the A2 horizo by plowing and discing, its continual fo mation from A2 horizon material, ar the addition of fresh organic matter fro crop residues. The A2 layer, howeve was much thinner, so the amount of pr ductive topsoil was dramatically less (b 16 centimeters) on the conventionall farmed soil. This difference in erosio which includes water, wind, and tilla effects, is equivalent to the removal over 0.4 centimeter of soil per year about 57 megagrams per hectare p year.

Supporting this difference in topso depths are the results of water erosio research (Weilgart Patten, 1982) co ducted on the same study area, exar ining both the organic and convention farms using the Alutin method (Ever and Riehle, 1980) to measure rill erosio (excludes sheet, wind, and tillage er sion). Field measurements, made duri a year when both farms were in wint

wheat, indicated that water erosion was 8.3 megagrams per hectare on the organic field and 32.4 megagrams per hectare on the conventional field, almost a four-fold difference. (About 1.1 megagrams of soil evenly distributed over a hectare of land would equal a layer of soil the thickness of one sheet of paper.) Some of the difference in water erosion might have resulted from a higher percent wheat cover on the organic farm plots due to a 12-day earlier planting time (Weilgart Patten, 1982).

Based on USLE estimates of water erosion (excludes wind and tillage erosion), average annual soil losses on the organically- and conventionally-farmed Naff soils were 7.8 and 20.4 megagrams per hectare, respectively. Both of these values are less than the average annual rate of water erosion of 31.5 megagrams per hectare in the Palouse area (Soil Conservation Service, Forest Service, and Economics, Statistics and Cooperatives Service, 1979); however, this average includes all slopes in the Palouse and would be smaller for 4.0 degree slopes (as in the study area) because average Palouse slopes are reported to range from 5.1 to 7.4 degrees (9 to 13 percent) (Mulla, 1986). Regardless, the USLE erosion estimate for the conventionally-farmed soil is 2.6 times that for the organically-farmed soil. In addition, the USLE rate of water erosion on the conventionally-farmed soil is almost two times the maximum soil loss tolerance value of 11.2 megagrams per hectare per year for Naff soils, whereas the USLE rate of water erosion on the organically-farmed soil is about two-thirds of the maximum tolerance value (Soil Conservation Service and Washington State University Agricultural Research Center, 1980). Soil loss tolerance, called the "T value", is the maximum rate of erosion of a specific soil that can occur without reducing its long-term crop production or environmental quality (Schertz, 1983). The T values commonly range between 4.5 and 11.2 megagrams per hectare per year. The water erosion data above indicate that the long-term productivity of the organically-farmed Naff soil is being maintained, whereas that of the conventionally-farmed Naff soil is being reduced because of high rates of soil erosion.

Tillage erosion is more insidious than water erosion and, on certain positions of many Palouse hills, it has caused more soil movement than that by water erosion (Kaiser, 1961). Tillage erosion results in net soil removal, such that soil physically moved downslope is not replaced by soil moving from a higher landscape position. It occurs mostly on upper segments of the slope, ridgetops, and mid-slope knobs and can be recognized in vertical soil walls (90 to 240 centimeters high) at fence lines where the farmer upslope has plowed toward the fence and the farmer downslope has plowed away from the fence (Busacca et al., 1985). Although data on soil loss by tillage erosion are sparse, Kaiser (1961) documented over 61 centimeters of soil removal on a Palouse farm hilltop over a 31-year period (1911-1942) and an additional 61 centimeters of soil removal in the next 17 years (1942-1959) from tillage erosion. Busacca et al. (1985) calculated the net soil loss by a single plowing (18 centimeters deep) from a ridgetop with a slope of less than 5.7 degrees (10 percent) to be 29 megagrams per hectare. The eroded soil is moved incrementally to the next lower slope segment where, if it is steeper than the ridgetop, a net soil loss also occurs; the soil is eventually deposited at the toe of the slope where there is a flatter gradient.

Kaiser (1961) attributed the most severe tillage erosion in the Palouse to the use of the moldboard plow and the heavy one-way disc; however, he noted that every cultivating operation moves some soil downhill on steep slopes. The two farm fields in the study area were both plowed so that the furrow slice was mostly turned uphill toward the boundary line of the two adjoining farms, yet occasionally turned downhill to keep soil from accumulating at the borderline (Figure 3). Although Kaiser (1961) documented no significant tillage erosion associated with turning the plow furrow uphill on slopes up to 5.7 degrees, with such a large difference (about 16 centimeters) in topsoil depths the conventional farmer may not have turned the plow furrow uphill as often as the organic farmer, resulting in more tillage erosion.

On other areas of the two farms where the furrow slice was turned downhill, differences in tillage erosion are to be expected due to the different crop rotation systems. In general, the level of tillage erosion in the Palouse increases in the order of the following operations: cultivating, chisel plowing with straight shanks, discing, chisel plowing with twisted shanks, and moldboard plowing (Dave Huggins, Washington State University, 1988, personal communication). Although actual amounts of tillage erosion are not known for the two farms in this study, a comparison can be made of the numbers of these different tillage operations on both farms (Table 5).

The number of moldboard plow operations over an 11-year period was 6.0 and 5.5 on the organic and conventional farms, respectively (Table 5). However, half of the moldboard plowing operations on the organic farm was done in the summer (July) when a green manure crop was turned under; the other half was done in the fall (September/October) when turning under wheat stubble. All moldboard plowing operations were done in the fall on the conventional farm. The amount of tillage erosion that occurs when a farmer plows under a green manure crop in the summer can be substantially less than that resulting from fall-plowed wheat stubble. During the summer, relatively dry soil with a green manure crop is turned over and results in the formation of large, stable

Table 5. Number of Tillage Operations* on the Two Farms over an 11-Year Cropping Period

Tillage Operations	Organic Farm	Conventional Farm
Moldboard Plowing		
Summer (turning under green manure crop)	3.0	0
Fall (turning under wheat stubble)	3.0	5.5
Discing (preparing soil for wheat)	0	4.4
Chisel Plowing with Straight Shanks (preparing soil for green manure crop)	4.0	0
Cultivating	13.0	11.0

* Excludes seeding, harrowing, rodweeding, and fertilizer-shanking operations which are not significant in tillage erosion.

clods and less relative soil movement downslope. Soil and organic residue conditions are quite different in the fall following a winter wheat crop; the soil is often more moist, organic residues are lower, and soil inversion from moldboard plowing results in smaller, less stable clods that are more easily transported downhill.

The organic farmer used a chisel plow with straight shanks 4 times in 11 years (when preparing the soil for the green manure crop), whereas the conventional farmer did not use a chisel plow. However, the conventional farmer used a disc 4.4 times in 11 years (for preparing the soil for winter wheat), whereas the organic farmer did not have any disc operations. Since discing is generally more disruptive to the soil than chisel plowing with straight shanks, more tillage erosion probably resulted on the conventional farm. The number of cultivation operations were slightly higher on the organic farm; however, they would contribute little to the amount of tillage erosion.

Loss of topsoil by erosion reduces organic matter, available water holding capacity, plant rooting depth, soil fertility, and crop yields (Uhland, 1949; Webber, 1964; Schertz et al., 1985; White, Jr. et al., 1985; Olson and Nizeyimana, 1988). It has been shown that winter wheat yields are reduced as topsoil loss is increased on Naff soils in the Palouse area (Bramble-Brodahl et al., 1985). It has also been reported that Naff and other similar soils (having strong argillic horizons) in the Palouse region will be more severely affected by continued erosion than very deep, uniform soils because of a reduction in effective rooting depth and loss of water and nutrient storage capacity (Busacca et al., 1985). Other researchers (Crosson and Stout, 1983; Larson et al., 1983; Olson and Nizeyimana, 1988) have found that soils with unfavorable or root-restricting subsoils have greater potential for serious losses in productivity due to erosion than do soils with favorable characteristics throughout a deep profile.

At current rates of water and tillage erosion for typical Naff and similar soils under conventional farming systems, it has been projected that all of the topsoil will be removed in 50 to 100 years, exposing the denser, less fertile subsoil argillic horizons and reducing crop yields by 30 percent (Busacca et al., 1985). These projected declines in yield ignore any concurrent yield increases due to improved technology over this 50-to-100-year period. However, uncontrolled erosion can substantially decrease the benefits from improved crop varieties and cultural practices, which have the greatest potential for increasing winter wheat yields on deep, relatively uneroded topsoils (Young et al., 1985). At some point, the increasing yield reduction from erosion may exceed the diminishing yield increase due to technical progress.

Average winter wheat yields for the past five years were 8 percent lower on the organic farm than on the conventional farm, but almost 13 percent higher than on a second conventional farm (with similar soils) adjacent to the organic farm (Reganold et al., 1987). The ability of the organic farmer to produce yields similar to neighboring conventional farmers, even after almost 80 years of farming without fertilizer, may be partly due to a reduction in soil erosion through effective management practices. The cost of this effective soil conservation-management system is the inclusion of crops less often in the rotation.

Crop rotation systems

The difference in erosion rates between the organic and conventional farms was most probably due to their different crop rotation systems; only the organic farm included a green manure crop in the third year of rotation and, as a result, had different tillage practices. Several advantages of green manure-based crop rotation systems with legumes or legume-grass mixtures have been reported which include reducing water erosion, maintaining or increasing yields, maintaining organic matter and soil nitrogen, assisting in weed and insect control, providing forage for livestock, and attracting and providing cover for wildlife (Kent, 1957; Schwendiman, 1957; Russell, 1973).

Comparisons of erosion rates for monoculture plots or nongreen manure based crop rotation plots (typical of many conventional farming systems versus green manure-based crop rotation plots (typical of organic farming systems) have indicated a significant reduction in soil erosion due to green manure-based crop rotations. For example, annual erosion rates were reported of 16.0 megagrams per hectare for corn following corn, 9.4 megagrams per hectare for corn following clover and 5.4 megagrams per hectare for corn following two years of grass-clover hay (Jamison et al., 1968). The same study also indicated annual erosion rates of 15.5 megagrams per hectare for soybeans following corn and only 4.5 megagrams per hectare for soybeans following grass-clover hay. In another study, Miller and Krusekopf (1932) reported that plots growing continuous wheat annually lost 22.7 megagrams per hectare of soil, those growing continuous corn annually lost 44.3 megagrams per hectare of soil, and those growing corn-wheat-clover in rotation annually lost 6.1 megagrams per hectare. Over a 10-year study period, Webber (1964) reported annual soil losses to be over 2.5 times greater for continuous corn than for a four-year rotation of corn-oats-hay-hay.

The organic farmer in this study used two years of alfalfa-grass mixtures and at least one year of Austrian winter pea for each 10-year cropping period. Horner et al. (1944) and Schwendiman and Kaiser (1960) found that alfalfa-grass mixtures work particularly well as green manure crops in the Pacific Northwest because they develop deep and extensive root systems and persistent organic residues. Kent (1957) reported that a crop rotation of legume-grass mixtures is needed for sloping lands, clay hilltops and other severely eroded lands in annual cropping areas of the Pacific Northwest. Horner et al. (1944) found that land in the Palouse, which has not been severely eroded and is in a relatively high state of fertility, does not require a green manure crop as frequently as land which is located on steeper slopes or has been more severely eroded; however, the most severely eroded and steepest sloping land should be farmed to a long-term cro

rotation in which alfalfa-grass mixtures are the dominant crops with cultivated crops representing a smaller proportion. They indicated that this practice furnished effective erosion control on highly erodible land and reduced runoff across other parts of the field. (It is interesting to note that the goal of the Conservation Reserve Program of the Food Security Act of 1985 is to convert 40 to 45 million acres of highly erodible U.S. cropland to permanent cover of mostly grass (with 12.5% going in trees) for at least 10 years (Hertz, 1988).)

Mannering et. al. (1964) revealed that a two-year legume-grass mixture in a crop rotation system exerts a greater erosion-reducing influence than a one-year legume-grass mixture in a similar rotation. Horner et al. (1944) and Kent (1957) indicated that the effectiveness of crop rotations with green manure legumes becomes progressively greater after several cycles of the rotation have been completed mainly due to increasing organic matter, i.e., the higher the soil organic matter, the lower the soil erodibility. Arden-Clarke and Hodges (1987) reported that a reduction in soil organic matter is probably the most important factor contributing to erosion in Great Britain.

Intermediate wheatgrass, which was used by the organic farmer in his alfalfa-grass mixture, is an excellent soil-building crop. For example, Stark et al. (1950) measured organic matter levels averaging 1.7% in cultivated soils after 26 years of a wheat-fallow crop rotation system; following a six-year cover of intermediate wheatgrass, organic matter was restored to 3.1%, a level slightly less than its original 3.4% in virgin soil. Based on erosion control, yield of roots, production and quality of hay, and adaptation to climatic and site conditions, intermediate wheatgrass was one of the top three grasses tested out of 20 grasses that made the best mixtures with alfalfa in the Palouse area of the Pacific Northwest (Woods et al., 1953).

The benefits of green manuring are governed by the kind of cover crop(s), the type of soil, the climatic conditions (particularly as they affect soil moisture relations), and the time and method of seeding (Uhland, 1958). For example, alfalfa-grass mixtures develop deeper, larger and more extensive root systems in soil conserving crop rotations than sweetclover or Austrian winter pea in the Pacific Northwest. In addition, sweetclover must be plowed down in two years, but if economic or other reasons demand it, an alfalfa-grass mixture can be left growing three to five years or more (Schwendiman and Kaiser, 1960). Austrian winter pea, if not managed correctly, can be an erosion-inducive green manure crop (Judd Melton, Soil Conservation Service, 1988, personal communication).

In addition to green manuring, some of the difference in water erosion rates on the two farms may have been due to differences in tillage practices. The organic farmer regularly used both chisel and moldboard plows, whereas the conventional farmer used the moldboard plow and disc in his tillage operations. Research has shown that chisel plowing can reduce water erosion compared with moldboard plowing and discing, because chisel plowing leaves the surface soil rough and covered with crop residues and penetrates compaction layers created by tillage operations (Johnson and Moldenhauer, 1979).

Conclusion

The long-term effects of organic farming versus conventional farming on soil properties of Naff silt loam were determined from both laboratory and field analyses. The most significant differences were that the organically-farmed soil had higher organic matter, polysaccharide, and water contents, greater cation exchange capacity, a larger and more active microflora, better structure and consistence for crop root growth and mechanical tillage, and thicker topsoil than did the conventionally-farmed soil. The data indicate that, in the long-term, the organic farming system was more effective than the conventional farming system in maintaining the productivity and tilth of the Naff soil and reducing its erosion rates. The difference in erosion was indicated by the difference in the thickness of productive topsoil on the two farms, the organically-farmed topsoil depth being about 16 centimeters greater than the conventionally-farmed topsoil depth.

This dramatic difference in topsoil loss was most likely due to a difference in crop rotations between the two farms; i.e., only the organic farm used a green manure legume crop in its rotation and it had different tillage operations. However, the benefits from green-manuring with a legume crop, along with the use of the chisel plow, could be included in the conventional farming system, which would result in higher organic matter levels, less soil erosion, and a reduction in fertilizer and pesticide requirements. If conventional farming methods are not modified, the loss of valuable Naff topsoil will continue.

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UPCOMING EVENTS

July 6-9. Third International Assembly on Conservation and the Environment, in Ann Arbor, Michigan. Contact Brian MacKenzie, Sierra Club, 19827 W Twelve Mile Road, Suite 344, Southfield, MI 48076, (313) 645-5131.

July 14-16. 15th Annual Summer Conference of the Natural Organic Farmers Association, in Williamstown, Massachusetts. Writer Noel Perrin will be the keynote speaker; 125 workshops on animal husbandry, farming, sustainable systems, nutrition, gardening, and more. Contact Julie Rawson, RFD #2, Barre, MA 01005, (508) 355-2853.

July 22-25. International Herb Growers and Marketers' 4th Annual Conference and Trade Show, in San Jose, California. Topics cover production, marketing, and business aspects of herb growing. Contact the International Herb Growers and Marketers Association, P.O. Box 281, Silver Springs, PA 17575.

July 30-August 2. The Soil and Water Conservation Society Annual Meeting, in Edmonton, Alberta. The program will focus on ways to achieve coordination and teamwork in natural resource conservation. Contact Alan Epps, SWCS, 7515 Northeast Ankeny Road, Ankeny, IA 50021-9764.

August 10. Field Crops and Wildlife Field Day, sponsored by the University of Tennessee Agricultural Experiment Station, at the Ames Plantation in Grand Junction, Tennessee. Contact the University of Tennessee Agricultural Experiment Station, Communications Office, 104 Morgan Hall, P.O. Box 1071, Knoxville, TN 37901-1071.

September 10-15. Sustainable International Development Workshop, cosponsored by the Institute of International Agriculture and the Michigan State University Department of Resource Development, at the Kellogg Biological Station of MSU. The workshop will demonstrate application of computer-assisted information systems for resource assessment, project planning, and implementation. Differences between more and less sustainable farming systems will be analyzed. The program is designed for professionals in international development. Contact Dr. George Axinn, Department of Resource Development, Michigan State University, East Lansing, MI 48824.

October 8. Farmer Participation in Research for Sustainable Agriculture, sponsored by the Kerr Center for Sustainable Agriculture at the University of Arkansas in Fayetteville. Topics include influencing the research agenda at land grant institutions, on-farm research methodology, appropriate topics and funding for on-farm research. For information contact Marcie Brewster at the toll-free number of the center for Appropriate Technology Transfer for Rural Areas (ATTRA), (800) 346-9140.

October 17-19. FOCUS Conference on Eastern Ground Water Issues, sponsored by the Association of Ground Water Scientists and Engineers, in Kitchener, Ontario, Canada. Conference papers will include agricultural and domestic impacts on ground water. For information contact FOCUS Eastern Conference, National Water Well Asociation, P.O. Box 182039, Department #017, Columbus, OH 43218.

November 2-4. The Place of Values in Food, Agriculture, and Environmental Systems, sponsored by the Agriculture, Food and Human Values Society, in Little Rock, Arkansas. Topics include farming, nutrition, and public policy. Contact Dr. Carolyn Sachs, Department of Rural Sociology, Pennsylvania State University, University Park, PA 16802.

Illinois research group does on-farm work

The Central Illinois Agriculture Research Farms, Inc., is a nonprofit group working with 14 farmers on research to correct soil compaction, bring back earthworms, and manage cover crops. Membership in the group gives invitations to in-field seminars at research sites, periodic newsletters, and the opportunity to be involved in research plans, says Dr. Bill Becker, a crop consultant and plant pathologist who directs the corporation. For information contact Becker at 1229 W Edwards, Springfield, IL 62704.

Use of organic amendments to increase the productivity of sand and gravel spoils: Effect on yield and composition of sweet corn

Sharon B. Hornick[1]

Abstract. *Crops grown on sand and gravel spoil areas are subject to temperature, moisture, and nutrient stresses due to the infertile, acidic, and coarse-textured properties of the spoil material. Additions of organic materials such as feedlot manure and sewage sludge compost applied at rates of 40, 80, and 160 Mg/ha were found to improve these spoil areas by providing (1) a more favorable pH for seedling germination and root development, (2) essential crop nutrients, and (3) a greatly increased water content of the spoils in the treated plots compared to fertilized controls. The manure-treated spoil plots had a higher water content than either the compost-treated spoils or the limed and fertilized control plots. In a drought year when the wastes were reapplied, both grain and stalk yields of sweet corn were highest for the manure-treated plots. The low heavy metal content makes these organic materials safe for use as soil conditioners. In addition, uptake and accumulation of toxic metals by sweet corn is generally less than other crops. The interaction between the kind and rate of organic amendment applied, the amount of rainfall in any given growing period, and the water content of the treated spoils determined the final nutrient composition of the stalks, leaves, and grain, as well as the grain and stalk yield.*

Key words: feedlot manure, sewage sludge compost, root development, mine spoils, soil water content, yields, sweet corn

Introduction

Farmlands extensively mined for sand and gravel need to be restored to their previous level of agricultural productivity. Reasons for restoration include improving the aesthetic appearance of the land, regaining a more favorable tax assessment, and producing crops for either animal feed or human consumption. However, the exposed subsoils that remain after mining can be very acidic, coarse-textured, and low in essential crop nutrients and soil organic matter (Hornick, 1982a; 1982b).

The addition of organic matter to marginal and degraded soils is important for restoring productivity. Application of organic materials of agricultural or municipal origin can improve soil structure and soil aggregation. They also increase the water-holding capacity and water infiltration into soil, thereby reducing nutrient runoff and erosion. Moreover, organic materials buffer the soil, allowing for a more favorable pH for seed germination and root development while providing essential nutrients for plant growth.

Some farmers have adequate amounts of on-farm organic materials, such as animal manures or crop residues, to maintain and restore soil productivity. Other farmers must obtain off-farm organic amendments for this purpose, including chemically stabilized sewage sludge, composted refuse and composted sewage sludge. These wastes, when suitably low in their content of heavy metals and certain toxic organic chemicals, can be safely used as soil conditioners and fertilizers (Hornick et al., 1984; Jacobs et al., 1987; Logan and Chaney, 1983).

The purpose of this study was to 1) determine how effectively two organic amendments, feedlot manure and composted sewage sludge, are in restoring the productivity of sand and gravel spoils, and 2) assess the effect of such practices on the yield and nutrient composition of sweet corn (*Zea mays* L.).

Materials and methods

Field plots were established in 1979 on an area near Beltsville, Maryland that had previously been mined for sand and gravel. Plots were sampled and the spoil materials were analyzed prior to treatment for organic matter content (Walkley-Black method, Jackson, 1958) and pH (spoil-to-water ratio, 1:1). Twenty-one plots, each 6.67 m x 6.67 m, were established to accommodate seven treatments and three replications in a randomized block design. A spacing of 4.57 m between each plot was used to prevent intermixing of plot soils.

Sewage sludge obtained from the Blue Plains Waste Treatment Plant in Washington, D.C. was composted according to the Beltsville Aerated Pile method (Willson et al., 1980) and applied at three rates of 40, 80, and 160 megagrams per hectare (Mg/ha). Similarly, beef feedlot manure from the Beltsville Animal Research Center facilities was applied at identical rates as above. The average elemental analyses of the two

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organic materials used are shown in Table 1. A fertilized control treatment (the zero rate) was also included in all cropping years. These plots received rates of chemical fertilizer recommended for sweet corn by the Maryland Agricultural Experiment Station, i.e., 179 kg N/ha as ammonium nitrate, 122 kg P/ha as triple superphosphate, and 112 kg K/ha as muriate of potash. Dolomitic limestone was applied to the fertilized control plots and to all plots which received 40 Mg/ha of either organic material.

For the plots that were amended with organic materials, lime requirements were determined from lime curves obtained by adding small increments of lime to amended soils placed in 270 ml cups. The treated soils were moistened and monitored for pH changes during a six-week equilibration period. Lime was not required by the 80 and 160 Mg/ha amended plots. Lime requirements for the fertilized control plots were determined by the method of Adams and Evans (1962). The organic amendments were rototilled into the upper nine inches of the spoil profile. "Silver Queen" sweet corn was planted on all plots.

The two organic materials were applied at the same rates and to the same plots in both 1979 and 1980. In 1981, no additions were made so that the comparative residual effect of the previously applied materials could be determined.

Concentrations of total copper (Cu), zinc (Zn), and cadmium (Cd) were determined each year in soil, diagnostic leaves, and stalk and grain samples that were obtained from each plot according to the method of Chaney et al. (1976). The soil samples were taken after the crop harvest. Analyses of grain for N, P and K, and the soil analyses for the

Table 1. Average elemental analysis of feedlot and sewage sludge compost used in field experiments with sweet corn.

Waste	Element N	P	K	Ca	Mg	Cd	Zn	Cu
	%					mg kg		
Manure	1.80	0.58	1.37	3.37	0.87	0.39	74	23
Compost	1.50	1.45	0.13	8.82	1.41	3.31	361	169

Table 2. Mean comparisons and analysis of variance for sand and gravel spoil parameters. Test was conducted over three years, the initial two years with various rates of feedlot manure or composted sewage sludge. Residual effects were observed in the third year.

YEAR	TREATMENT Mg/ha[1]	PARAMETER[2] pH	OM %	CEC	Ca	Mg	K	N	P
				meq/100g				mg/kg	
1	Control	7.42 b	0.76 c	6.9 e	5.96 c	0.66 b	0.18 d	285 d	432 d
	Compost 40	7.71 a	1.50 c	13.1 cd	12.43 b	0.43 b	0.16 d	776 cd	957 cd
	Compost 80	7.71 a	2.53 bc	18.9 ab	18.03 a	0.57 b	0.17 d	1584 bc	1792 b
	Compost 160	7.70 a	4.23 b	23.6 a	22.4 a	0.90 b	0.25 cd	2577 b	2939 a
	Manure 40	6.83 c	3.07 bc	9.4 de	6.46 c	1.50 b	0.48 bc	1261 cd	612 cd
	Manure 80	6.52 d	2.77 bc	9.7 de	5.37 c	1.63 b	0.58 b	1878 bc	723 cd
	Manure 160	6.76 c	8.47 a	15.8 bc	7.80 bc	4.33 a	1.14 a	4769 a	1241 bc
	TRT effect	**[3]	**	**	**	**	**	**	**
	REP effect	**	-	-	-	-	-	-	-
2	Control	7.41 cd	0.87 e	6.2 f	5.13 g	0.73 e	0.28 d	440 e	501 e
	Compost 40	7.80 a	2.43 d	14.6 d	13.63 c	0.63 e	0.34 d	1826 d	2188 c
	Compost 80	7.74 ab	4.40 bc	19.5 b	18.33 b	0.90 e	0.25 d	2909 c	3585 b
	Compost 160	7.64 abc	8.30 a	23.2 a	21.47 a	1.33 d	0.32 d	5930 a	6270 a
	Manure 40	7.52 bcd	3.97 c	11.0 e	7.80 f	2.13 c	1.04 c	2320 cd	979 de
	Manure 80	7.37 d	5.83 b	14.5 d	9.20 e	3.10 b	2.18 b	4026 b	1522 cd
	Manure 160	7.45 cd	8.60 a	17.8 c	10.63 d	4.53 a	2.50 a	5656 a	2152 c
	TRT effect	*[4]	**	**	**	**	**	**	**
	REP effect	-	-	-	-	-	-	-	-
3	Control	6.63 c	0.80 d	7.8 d	6.47 c	0.97 d	0.32 d	355 e	470 f
	Compost 40	7.14 ab	1.80 cd	13.2 cd	11.63 bc	1.30 d	0.22 d	1005 d	1348 c
	Compost 80	7.36 a	3.22 b	20.3 ab	18.40 a	1.67 cd	0.26 d	1943 b	2533 b
	Compost 160	7.43 a	6.60 a	25.1 a	22.56 a	2.10 c	0.41 cd	3678 a	4932 a
	Manure 40	6.85 bc	2.80 bc	10.5 d	7.80 bc	2.03 c	0.72 bc	1366 cd	737 de
	Manure 80	6.92 bc	3.43 b	12.9 d	7.73 bc	4.33 b	0.82 b	1833 bc	899 d
	Manure 160	6.64 c	6.87 a	19.0 bc	12.13 b	5.50 a	1.38 a	3837 a	1667 c
	TRT effect	**	**	**	**	**	**	**	**
	REP effect	-	-	-	-	-	-	-	-
	YEAR effect	**	**	-	-	**	**	**	**
	YEAR*TRT	**	-	-	-	*	**	**	**

[1] Mg = megagrams = 10^6 gm = metric tons.
[2] Means within a column not followed by the same letter differ according to the LSD ($P < 0.05$).
[3] Denotes significance at the $P < 0.01$ level for treatment (TRT) and replication (REP) main effects within each year and for year (YEAR) effects and year by treatment (YEAR*TRT) interactions over three years.
[4] Denotes significance at the $P < 0.05$ level as above.

cation exchange capacity (CEC), Ca, Mg, and K were performed by the analytical service laboratories at The Pennsylvania State University. Grain and stalk yields were measured at harvest. Soil organic matter was determined colorimetrically (Walkley-Black method, Jackson, 1958). All analyses of the soil and plant materials and the organic amendments are reported on a dry weight basis. Strength of soil crusting was measured in the second cropping year using a Soil Test[2] pocket penetrometer. Twenty penetrometer readings were taken on each plot.

Results of the randomized block design study were evaluated using analysis of variance and SAS (Statistical Analysis System) software. Least Significant Difference (LSD) values were used to separate significant means at the 0.05 level of probability. Letters implying significant differences between treatments have been used for mean separations within years. Significant treatment effects and replication (rep) effects within years, and significant year and year x treatment interactions among years are noted by asterisks.

Results and discussion

The yearly soil or spoil analyses presented in Table 2 show the highly significant effect of treatment for all parameters measured in all three years. As expected, the organic matter content of the sand and gravel spoils increased with increasing rates of each organic amendment.

The relative increases in the macronutrient levels were directly proportional to the initial macronutrient content in the organic amendment and to the rate applied. For example, composted sewage sludge had much higher levels of P and Ca than the feedlot manure because the sludge had received chemical and lime stabilization at the treatment plant. This, in turn, resulted in higher levels of P and Ca in those plots that were amended with compost as compared to manure.

Table 3. Mean comparisons and analysis of variance for macronutrient concentrations in sweet corn grain, and grain and stalk yields grown for three years on amended sand and gravel spoils.

YEAR	TREATMENT Mg/ha[1]	GRAIN[2] N	GRAIN[2] P	GRAIN[2] K	GRAIN[2] Yield	STALK Yield
			%		kg/ha	kg/ha
1	Control	2.54	0.33 c	0.75 cd	1127	3761 ab
	Compost 40	2.55	0.32 c	0.72 d	1725	4526 a
	Compost 80	2.48	0.34 c	0.77 cd	1311	4212 a
	Compost 160	2.24	0.34 c	0.80 bcd	1492	4685 a
	Manure 40	2.28	0.38 b	0.84 bc	959	2224 c
	Manure 80	2.47	0.40 ab	0.90 ab	1450	2718 bc
	Manure 160	2.66	0.42 a	0.96 a	1515	4884 a
	TRT effect	—	**[3]	**	—	**
	REP effect	—	—	—	—	—
2	Control	2.49	0.42	0.84 b	1264 b	4004
	Compost 40	2.44	0.41	0.76 b	1215 b	4406
	Compost 80	2.47	0.45	0.77 b	1200 b	5278
	Compost 160	2.52	0.46	0.76 b	2014 ab	6584
	Manure 40	2.55	0.50	0.91 b	2350 ab	5915
	Manure 80	2.49	0.49	0.85 b	3245 a	5043
	Manure 160	2.78	0.51	1.08 a	3290 a	5040
	TRT effect	—	—	**	*	—
	REP effect	*[4]	—	—	—	—
3	Control	2.84 ab	0.42	0.77	1213	4902 ab
	Compost 40	2.35 c	0.42	0.75	892	4314 b
	Compost 80	2.67 ab	0.43	0.76	1127	5079 ab
	Compost 160	2.69 ab	0.43	0.71	1333	5667 a
	Manure 40	2.58 bc	0.43	0.76	1619	5727 a
	Manure 80	2.86 a	0.50	0.87	894	5298 a
	Manure 160	2.70 ab	0.46	0.78	996	5765 a
	TRT effect	*	—	—	—	*
	REP effect	—	—	—	—	—
	YEAR effect	**	**	*	**	**
	YEAR*TRT	*	—	—	**	—

[1] Mg = megagrams = 10^6 gm = metric tons.
[2] Means within a column not followed by the same letter differ according to the LSD ($P < 0.05$).
[3] Denotes significance at the $P < 0.01$ level for treatment (TRT) and replication (REP) main effects withi each year and for year (YEAR) effects and year by treatment (YEAR*TRT) interactions over three year
[4] Denotes significance at the $P < 0.05$ level as above.

Similarly, manure had much higher levels of K and Mg than the compost and, consequently, the manure-treated plots had higher levels of these two nutrients than did those treated with compost.

A highly significant year effect was seen for all nutrients except Ca. Although the Ca levels in sludge and manure differed greatly, the amounts added each year had less of an effect on the exchangeable soil Ca levels compared with marked increases shown for the other soil nutrients. The large amount of total Ca in the soil profile may have interfered with the exchangeable cation determinations and that for CEC. Because Ca is the major cation contributing to soil CEC, the CEC did not change over years with treatment and, therefore, the year effect was not significant. The year X treatment interactions were not significant for organic matter, CEC an Ca. However, the level of some nutrient began to decline in the third or residua year when organic materials were nc applied (Table 2).

The soil pH was significantly highe for the compost-treated rather than th manure-treated plots because of the hig

Table 4. Rainfall in millimeters (mm) received fc a four-month period on compost- and manur treated sand and gravel spoil plots cropped fc three years with sweet corn.

MONTH	YEAR 1979	1980	198
May	82	78	9
June	111	56	7
July	112	160	7
August	132	41	8
Total	436	256	32

[2]Trade names are included for the benefit of the reader and do not imply endorsement by the USDA.

lime content of the sewage sludge compost. In the second year, the differences in pH due to treatment were not as significant. In the third or residual year, highly significant differences in pH were seen between the organic amendments, but not among the treatments for each amendment. The pH levels started to decline in the third year, but the compost-treated plots maintained the highest pH levels, indicating that compost was a more effective buffering agent than manure.

Macronutrient analyses of sweet corn grain, and yield of grain and stalks over the three-year period are shown in Table 3. There were no significant differences in the N content of grain among all treatments for the two years that the organic amendments were applied. Significant differences in grain N did appear among treatments during the third year. The highest levels were associated with the high rates of compost and manure and the fertilized control plot. These treatments were significantly higher in grain N than those from the 40 Mg/ha plots. These results indicate that the greater total amount of organic N applied with both organic amendments at the 80 and 160 Mg/ha rates continued to mineralize and keep pace with crop demand.

The control plots were fertilized and limed since preliminary data showed that there would be only negligible plant growth and yield on unfertilized and unlimed plots. The original pH of the control plots was 4.9. The high grain N level for the control is consistent with the fact that the control plots received N, P, and K fertilizer and limestone applications in each of the three years. Plots which received 40 Mg/ha of compost in each of the first two years were substantially lower in mineralizable N than the other treatments. A significantly lower grain and stalk yield during the third year supports this conclusion. A significant replication (rep) effect is seen in the second year that is probably due to differences in grain N values within treatments. This variability may help explain why the average treatment values were not significantly different for grain N.

In contrast, the only highly significant treatment effect for P occurred in the first year, but not in the two succeeding years. Although the compost contained a higher level of P than did the manure, sweet corn grown on the manure-treated plots at all three rates, was significantly higher in grain P than the compost-treated plots for all rates and higher than the fertilized control. A possible explanation for this difference may have been that manure P was in a more readily available form than compost P (Chauhan et al., 1979). The sewage sludge used in making the compost was subjected to chemical treatment and lime stabilization which could have affected the P mineralization rate and availability after composting.

During the first two years, the K content of the sweet corn grain was significantly higher for the manure-treated plots than for the compost-treated plots as well as the fertilized control. This result is not unexpected because the manure contained ten times the K levels compared to compost. Significant treatment differences for grain K were not observed in the residual year even though the manure-treated plots remained somewhat higher in K than the compost-treated plots.

There were no consistent treatment effects for grain yields in the first and third years (Table 3). Significant treatment differences were observed in the second year after addition of the organic amendments, with grain yields for the manure being much higher than for both the compost-treated plots and the fertilized control. In contrast, there were

Table 5. Mean comparisons and analysis of variance for concentrations of Cd in soil and leaf, stalk, and grain of sweet corn grown on sand and gravel spoils treated with feedlot manure and composted sewage sludge.

YEAR	TREATMENT Mg/ha[1]		SOIL[2]	LEAF[2]	STALK[2]	GRAIN[2]
			mg/kg			
1	Control		0.02 d	0.24 c	0.21 c	0.04 c
	Compost	40	0.25 c	0.44 bc	0.38 bc	0.10 bc
	Compost	80	0.50 b	1.01 ac	0.56 bc	0.18 ab
	Compost	160	0.97 a	0.97 ab	0.96 a	0.27 a
	Manure	40	0.03 d	0.29 c	0.47 bc	0.13 bc
	Manure	80	0.05 d	0.24 c	0.34 bc	0.08 c
	Manure	160	0.07 cd	0.31 c	0.48 b	0.18 ab
	TRT effect		**[3]	*[4]	**	**
	REP effect		—	—	—	—
2	Control		0.00 d	0.10 c	0.11 c	0.04 b
	Compost	40	0.58 c	0.21 bc	0.32 bc	0.06 b
	Compost	80	1.10 b	0.31 b	0.49 b	0.11 b
	Compost	160	2.17 a	0.72 a	1.27 a	0.23 a
	Manure	40	0.02 d	0.30 bc	0.32 bc	0.10 b
	Manure	80	0.04 d	0.17 bc	0.22 bc	0.04 b
	Manure	160	0.05 d	0.27 bc	0.26 bc	0.10 b
	TRT effect		**	**	**	**
	REP effect		—	—	—	—
3	Control		0.00 d	0.10 d	0.08 d	0.04
	Compost	40	0.37 c	0.30 b	0.21 bc	0.04
	Compost	80	0.84 b	0.36 b	0.33 ab	0.05
	Compost	160	1.66 a	0.58 a	0.43 a	0.08
	Manure	40	0.00 d	0.18 c	0.17 cd	0.05
	Manure	80	0.00 d	0.12 cd	0.07 d	0.05
	Manure	160	0.04 d	0.14 cd	0.16 cd	0.07
	TRT effect		**	**	**	—
	REP effect		—	*	—	—
	YEAR effect		**	**	**	**
	YEAR*TRT		**	—	**	—

[1] Mg = megagrams = 10^6 gm = metric tons.
[2] Means within a column not followed by the same letter differ according to the LSD ($P < 0.05$).
[3] Denotes significance at the $P < 0.01$ level for treatment (TRT) and replication (REP) main effects within each year and for year (YEAR) effects and year by treatment (YEAR*TRT) interactions over three years.
[4] Denotes significance at the $P < 0.05$ level as above.

significant differences for stalk or vegetative growth in the first and third years, but not for the second year when the organic materials were reapplied. Stalk yields were lowest in the first year but somewhat similar in the second and third years.

Some of the differences in grain and stalk yield may have also been affected by the amount of rainfall received in the three cropping years. During the first cropping year, 436 mm of rainfall was received during the growing season compared with only 256 mm the second year; most precipitation occurred in July just before tasseling (Table 4).

Seedling emergence on the fertilized control plots was much lower than on the plots treated with organic amendments. This pattern of emergence appeared to be related to surface crusting and, thus, soil crust strength measurements were taken two weeks after the sweet corn was planted. The soil water content on each plot was also measured at this time. Figure 1 shows that the strength of the soil surface crust was much higher on the fertilized control plots (zero rate) compared with those treated with compost or manure. Moreover, the crust strength was even lower on the manure-treated plots compared to the compost-treated plots. As reported earlier, the gravimetric water content was substantially higher on the manure-treated plots than on those treated with compost (Hornick, 1982a; 1987). All plots treated with organic amendments had substantially higher water contents than the fertilized control plots.

Despite the drought conditions during grain filling the second year, the grain yields on the manure-treated plots were the highest in this study. This was attributed to a possible higher water-holding capacity of the manure, which provided for greater retention and storage of rainfall, especially during periods of excessive rainfall as occurred in July 1980. Such differences in grain yield associated with either organic amendment were not observed in the third (residual) year because of the limited amount of rainfall (323 mm) which was rather evenly distributed throughout the growing season. However, stalk yields for the control and 40 and 80 Mg/ha compost-treated plots were somewhat lower than the other treatments.

Conflicting differences in yield due to seasonal variations were also reported by Sahs and Lesoing (1985). They found that in drought years, higher sweet corn yields were obtained on plots treated with beef feedlot manure than on those receiving chemical fertilizer. However, in years of normal rainfall, the chemically fertilized plots generally had higher yields than did those receiving organic amendments.

Table 5 shows that the Cd levels of soil, leaf, stalk and grain of sweet corn grown on spoils treated with feedlot manure and composted sewage sludge were significantly higher for the compost-treated plots than for manure, and for all rates and years. The Cd content of the manure was very low, i.e., one-tenth that of the sludge compost. It is not surprising, therefore, that soil Cd levels in the manure-treated plots were similar to the control plots. The same trend wa observed in leaf and stalk samples; C levels increased with increasing sludg compost rates, while the Cd levels c these tissues on the control plots were in general, not significantly differen from the manure plots. Grain Cd level varied widely in the first year the organi amendments were applied, and increas ing the rates of compost increased grai Cd levels. In the second year, althoug soil Cd levels greatly increased due t the second application of compost, onl the Cd level in the grain from the 16 Mg/ha compost-treated plot was sig nificantly different from the other treat ments. In the third or residual year there was no significant differenc among treatment rates and amendment for grain Cd even at the 160 Mg/ha rate

As with Cd, soil and leaf Zn level increased with increasing rates of com post and were much higher for plots re ceiving compost than manure, and fo all years (Table 6). Although soil Z

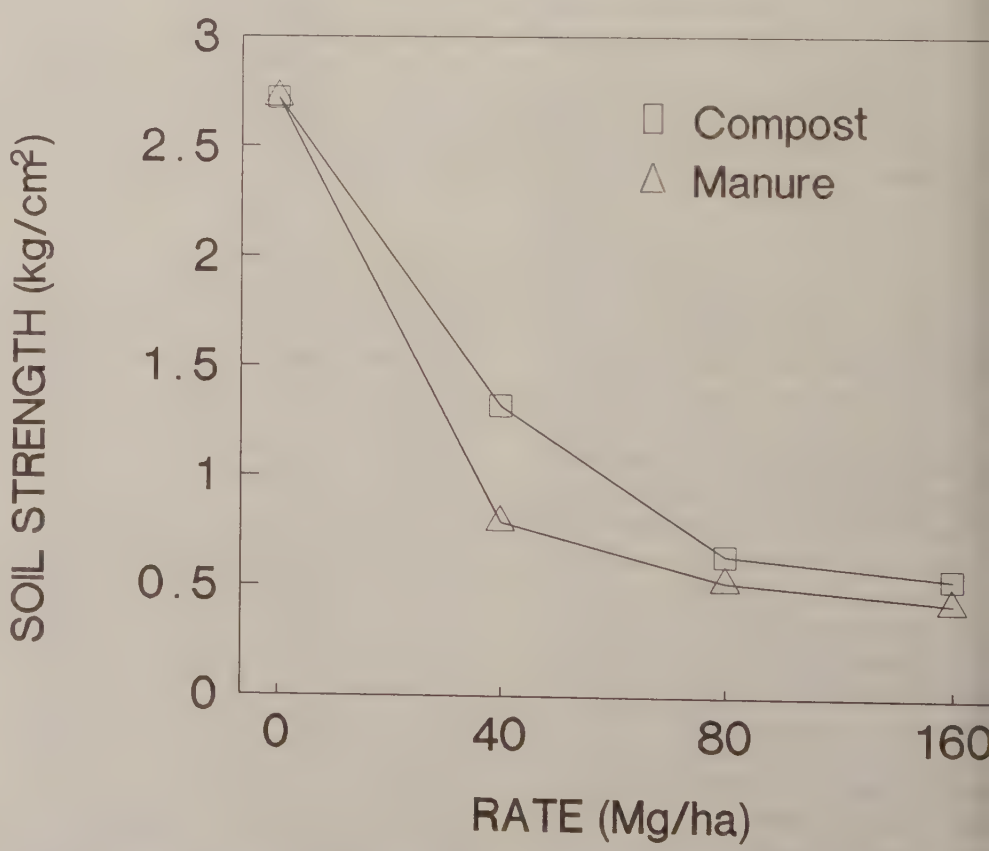

Figure 1. Surface crusting or strength (kg/cm²) of sand and gravel spoil plots six weeks after receiving various rates of either feedlot manure or sewage sludge compost (Mg/ha) and two weeks after planting sweet corn.

Table 6. Mean comparisons and analysis of variance for concentrations of Zn in soil and leaf, stalk, and grain of sweet corn grown on sand and gravel spoils treated with feedlot manure and composted sewage sludge.

YEAR	TREATMENT Mg/ha[1]		SOIL[2]	LEAF[2]	STALK[2]	GRAIN[2]
			mg/kg			
1	Control		18.7 d	15.0 d	21.4 b	23.9
	Compost	40	38.1 c	21.0 bcd	30.9 bc	24.6
	Compost	80	66.4 b	25.3 ab	32.2 b	26.0
	Compost	160	114.2 a	27.8 a	59.5 a	26.9
	Manure	40	24.5 c	15.9 cd	66.2 a	24.6
	Manure	80	19.9 c	23.7 ab	50.9 a	26.0
	Manure	160	34.1 c	21.2 bc	58.9 a	30.2
	TRT effect		**[3]	**	**	—
	REP effect		—	—	—	—
2	Control		19.8 d	17.1 d	15.4 c	27.1 c
	Compost	40	66.7 c	19.6 d	30.2 b	26.2 c
	Compost	80	116.4 b	25.1 b	32.8 b	34.6 b
	Compost	160	289.0 a	30.8 a	48.0 a	41.3 a
	Manure	40	25.4 cd	18.4 d	29.2 b	29.5 bc
	Manure	80	25.9 cd	20.6 cd	30.8 b	33.3 b
	Manure	160	41.5 cd	24.2 bc	39.4 ab	33.2 b
	TRT effect		**	**	**	**
	REP effect		—	—	—	—
3	Control		19.9 e	12.9 d	15.3 d	23.3
	Compost	40	49.7 c	18.4 c	26.2 b	26.5
	Compost	80	92.1 b	25.1 b	27.6 b	29.6
	Compost	160	180.1 a	27.9 a	32.3 a	27.1
	Manure	40	24.0 de	17.9 c	16.8 cd	26.6
	Manure	80	21.0 e	17.9 c	14.7 d	24.8
	Manure	160	38.8 cd	22.5 b	20.6 c	38.0
	TRT effect		**	**	**	—
	REP effect		—	—	—	—
	YEAR effect		**	*[4]	**	**
	YEAR*TRT		**	—	**	*

[1] Mg = megagrams = 10^6 grams = metric ton.
[2] Means within a column not followed by the same letter differ according to the LSD ($P < 0.05$).
[3] Denotes significance at the $P < 0.01$ level for treatment (TRT) and replication (REP) main effects within each year and for year (YEAR) effects and year by treatment (YEAR*TRT) interactions over three years.
[4] Denotes significance at the $P < 0.05$ level as above.

levels were much higher for compost-treated than manure-treated plots in the first year, the Zn levels in the stalks were unexplainedly higher in the manure-treated samples. In subsequent years, stalk Zn levels were higher in sweet corn grown on the compost-treated than on the manure-treated plots. As observed for Cd, Zn levels in grain showed a highly significant treatment effect only in the second year, with the 160 Mg/ha compost rate having the highest grain Zn level.

Soil Cu levels showed a highly significant treatment difference in all years due to the additive effect of rate and type of organic amendment used (Table 7). Generally, the manure-treated plots for leaf, stalk and grain had lower levels of Cu than did the compost-treated plots. Because Cu is strongly bound by organic materials in the soil, and the manure contained so little Cu compared with compost, it is likely that the increased levels of organic matter in the manure-treated plots could bind or complex the small amount of soil Cu, rendering it less available for plant uptake.

Because of treatment differences due to the presence or absence of organic amendments in the three years, it was not surprising that the year effects and the year X treatment effects were highly significant for soil Cd, Zn and Cu.

Conclusions

Sand and gravel spoil areas are generally heterogeneous in mineral composition due to the previous mining operations. Spoils are generally coarse-textured, poorly structured, low in organic matter, and deficient in both macro- and micronutrients that are essential for optimum plant growth. Plants grown on these spoil materials without some amelioration of their adverse properties are subject to temperature, moisture, and nutrient stresses even under normal weather and climatic conditions.

This research has shown that the addition of lime and chemical fertilizers alone is not adequate to restore these sand and gravel spoils to an acceptable level of productivity and stability over the short-term. Organic amendments provided a buffer for preventing wide fluctuations in pH, an array of essential macro- and micronutrients, and improved soil physical properties. All of these modifications help overcome the detrimental stresses on plants caused by high temperatures, drought and nutrient deficiencies.

Differences in mineral composition of the organic amendments were largely responsible for differences in the nutrient and chemical content of stalks, leaves and grain of sweet corn. Inconsistencies in grain and stalk yields were attributed to an interaction between the kind and rate of organic amendment applied, the amount of rainfall in any given growing period, and the water content of the treated spoils.

Differences in the N content of the grain reflected differences in N mineralization rates between the organic amendments. Grain P levels also reflected differences in the amendments with respect to the levels of P available for uptake. Similarly, Cu which is strongly bound by soil organic matter was less available for plant uptake as evidenced by the lower levels of Cu that were observed in samples from the amended compared with control plots. Although Zn levels generally increased in the leaf, stalk and grain as the application rate of each amendment increased, undesirable or phytotoxic levels of Zn were not observed. The level of grain Cd increased only during the first two years when compost was applied, with the greatest increase occurring at

Table 7. Mean comparisons and analysis of variance for concentrations of Cu in soil and leaf, stalk and grain of sweet corn grown on sand and gravel spoils treated with feedlot manure and composted sewage sludge.

YEAR	TREATMENT Mg/ha[1]	SOIL[2]	LEAF[2]	STALK[2]	GRAIN[2]
		mg/kg			
1	Control	4.29 d	7.89 a	4.02	4.50
	Compost 40	13.14 c	7.79 a	4.46	4.24
	Compost 80	21.93 b	7.12 ab	4.02	4.37
	Compost 160	39.71 a	5.99 bc	3.91	4.08
	Manure 40	5.15 d	4.72 c	3.75	3.31
	Manure 80	4.16 d	5.94 bc	4.18	3.52
	Manure 160	6.37 d	5.35 c	4.08	3.75
	TRT effect	**[3]	*[4]	—	—
	REP effect	—	—	—	—
2	Control	3.62 d	8.67	4.53 cd	4.05 cd
	Compost 40	25.8 c	10.38	4.75 bc	3.88 d
	Compost 80	43.9 b	10.96	5.09 ab	4.81 ab
	Compost 160	87.2 a	14.00	5.36 a	5.23 a
	Manure 40	4.71 d	13.21	3.92 e	4.41 bcd
	Manure 80	5.00 d	9.27	3.57 e	4.71 abc
	Manure 160	7.28 d	11.88	4.04 e	5.24 a
	TRT effect	**	—	**	**
	REP effect	—	—	—	—
3	Control	4.02 d	8.10 a	3.87 bc	3.91
	Compost 40	18.5 c	6.50 c	3.03 de	3.23
	Compost 80	33.5 b	7.37 b	4.04 ab	4.03
	Compost 160	69.7 a	8.50 a	4.57 a	3.81
	Manure 40	4.67 d	6.10 c	3.37 cd	3.05
	Manure 80	4.51 d	5.13 d	2.74 e	3.28
	Manure 160	6.81 d	5.30 d	2.69 e	3.56
	TRT effect	**	**	**	—
	REP effect	—	—	—	—
	YEAR effect	**	**	**	**
	YEAR*TRT	**	—	**	—

[1] Mg = megagrams = 10^6 gm = metric tons.
[2] Means within a column not followed by the same letter differ according to the LSD ($P < 0.05$).
[3] Denotes significance at the $P < 0.01$ level for treatment (TRT) and replication (REP) main effects within each year and for year (YEAR) effects and year by treatment (YEAR*TRT) interactions over three years.
[4] Denotes significance at the $P < 0.05$ level as above.

the 160 Mg/ha rate. There were no differences in grain Cd among treatments in the residual year. Although grain and leaf Cd levels increased in all years on the compost-treated plots, these levels are not excessive and should not be toxic if consumed (Chaney et al., 1987).

These results show that sand and gravel spoils can be restored to a higher level of productivity with appropriate additions of lime, chemical fertilizers and organic materials. Furthermore, additions of organic amendments to spoils or soils can increase yields in drought years because of increased infiltration, retention, and storage of rainfall. Further studies are needed to determine how organic amendments differ in their ability to change the chemical and physical properties of spoil materials, as well as eroded and degraded soils, and how such changes affect the yield and quality of crops.

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The Good Food Guide, listing organic farms in New York state which sell products from vegetables to venison and maple syrup and flowers, is now available. It is $3 from the Natural Organic Farmers' Association of New York, P.O. Box 454, Ithaca, NY 14851.

Using crop diversity to manage pest problems: Some California examples

Mary Louise Flint and Philip A. Roberts

Abstract. *Moderate to large scale California growers (as well as small scale ones) manipulate cropping patterns in a number of ways to reduce pest problems. Crop rotation, which can be defined as diversifying crops over time, is used to manage selected pests, primarily weeds, pathogens, and nematodes. As a substitute for pesticides, crop rotation has been most rewarding in the control of nematodes; sugarbeet cyst and root knot nematode examples are detailed. Some pests that invade fields from nearby areas can be managed by modifying adjacent cropping patterns or practices; Pierce's disease of grapes, sugarbeet yellows and border harvesting of alfalfa are given as examples. Finally, multiple crops can be grown within a single field or orchard. Although this approach is not widely practiced by many California growers, two examples of systems where intercropping has been shown to limit pest numbers without the use of pesticides are described: intercropping of cotton with alfalfa and companion planting oats when seeding alfalfa. These examples show that using crop diversification to manage pests is feasible, but growers must be strongly motivated to make the necessary changes in cropping patterns. Most of the systems that have been widely adopted are those for which few other economically feasible methods were available.*

Key words: cropping patterns, weeds, insects, pathogens, nematodes, pest management, crop rotation, crop diversity, intercropping, multiple crops, economic feasibility

Compared to natural ecosystems, modern agricultural ecosystems are simplified. Age and genotype of crop plants are usually fairly uniform. Weeds are eliminated as much as possible and species diversity is limited to a few crop plants. Land is leveled, fields are uniformly irrigated and fertilized, shade is eliminated—in general the physical diversity of the environment is decreased compared to noncultivated areas. Because agricultural ecosystems provide less variety of food and shelter and often no permanent habitat, the numbers of species (or species diversity) of plants, animals, and microorganisms is greatly reduced compared to natural ecosystems. However, the total number of individuals may not be reduced—in fact, as any pest manager knows, a monocultural agroecosystem can provide an ideal habitat for rapid population growth (or outbreaks) of many pest species. Some have argued that pest problems could be decreased by increasing the diversity of crops or other types of plants (e.g., ground covers and weeds) in a cultivated area (e.g., Altieri, 1985); a few small scale organic farmers already apply this principle to their operations by routinely intercropping rows or individual plants of different crops or crops and noncrops. However, the generalization that diversity decreases pest problems does not hold true for many types of situations and pests (Levins and Wilson, 1980; Risch et al., 1983) and probably must be evaluated on a case by case basis. The purpose of this paper is not to discuss the theory of increasing ecological diversity to improve pest management in general, but to present some examples of the types of changes in cropping patterns that have led to improved pest control in California on medium to large scale farms.

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Crop rotation: Diversification over time

Pests with limited mobility, whose primary reservoir is the field itself and especially those which also have a limited host range, are sometimes amenable to management by changing the type of crop grown in the infested field for a period of time—a practice commonly called crop rotation. The changing of crop sequences as compared with growing the same crop in the same field year after year can really be seen as diversifying the ecosystem over time.

Although crop rotation traditionally has been one of the cornerstones of good farming, it is much less widely practiced than in earlier decades. The originally recognized benefits of crop rotation—better use of nutrients, improvement of soil texture, water economy and control of soil pathogens, nematodes and weeds—are now met with synthetic fertilizers, modern tillage and irrigation equipment, soil amendments, soil fumigants and herbicides, and growers often have felt that the increased marketing efforts and specialized equipment required for a variety of crops in rotation could not be justified (Palti, 1981). However, because of the reduced availability of soil applied pesticides—and especially nematicides—crop rotation is again being viewed critically as a management alternative.

Crop rotation is a feasible alternative only for certain types of pests and situations. Both the biological requirements of the pest and the agronomic/

economic considerations of the farming situation must be taken into account. The source of the pest inoculum must be within the field; the pest cannot be so mobile that it is likely to move in from adjacent fields or other areas. Good examples of nonmobile pests are soil and root-dwelling nematodes, soilborne pathogens that do not produce airborne spores, and weeds such as nutsedge that propagate primarily by vegetative means. In addition, the host range of the pest must not be so wide that practical alternate crops are not available (although fallowing is sometimes an option). Finally, most of the pest population must die off after a year or two in the absence of living host plants.

Several agronomic/economic considerations affect the feasibility of crop rotation for pest control. There must be alternate crops that are economically feasible, and any revenue lost by growing an alternate crop must be weighed against the costs of other pest control options. In addition, the required rotation sequence must not upset some other aspect of crop production; for instance, production of the alternate crop must not require the use of herbicides that cannot be used prior to growing other crops within the rotational sequence.

Crop rotation is used widely in California, but it is used primarily to improve soil texture, conserve water, or to provide better weed control by rotating to crops that have growth habits, cultural practices or herbicides that improve suppression of troublesome weeds. Only a handful of rotations are used that are directed primarily at managing pests other than weeds without the use of pesticides. The control of cyst and root knot nematodes is discussed below; other examples include the control of Verticillium wilt in cotton (UC Statewide IPM Project, 1984) and corky root in lettuce (UC Statewide IPM Project, 1985). No important insect pests are currently candidates for control through rotation practices in California.

Sugarbeet cyst nematode: The sugarbeet cyst nematode, *Heterodera schachtii,* is a major pest in many of California's sugarbeet growing regions. Cyst nematodes parasitize the plant root and impair water and nutrient uptake, often seriously reducing yields. Crop rotation, usually involving a 3 to 7 year break of nonhost crops between sugarbeet crops, is currently the main control strategy for the pest. Hosts are limited to plants in the beet (and spinach) and crucifer families. However, weed control in alternate crops is critical, because numerous common weed species, especially mustards, host the nematode and will allow it to maintain or increase its populations. Soil sampling programs, population decline rates, and economic thresholds have been developed to determine when rotation is necessary and how long rotation out of host crops must last to sufficiently reduce the nematode in a given field (Roberts and Thomason, 1981). Figure 1 shows the number of years of rotation to nonhosts necessary to reduce sugarbeest cyst populations below economically damaging levels based on the estimated (from soil sampling) population level at rotation commencement and an annual decline rate of nematode populations under nonhosts of 50 percent as determined by Roberts et al. 1981.

Cotton root knot nematode: Root knot nematodes (*Meloidogyne* spp.) are less amenable to management through rotation than are cyst nematodes because they have wide host ranges and cause economic damage to many field and vegetable crops. Furthermore, the closely related common species of *Meloidogyne* are difficult to distinguish from one another yet differ in their ability to reproduce on and damage different

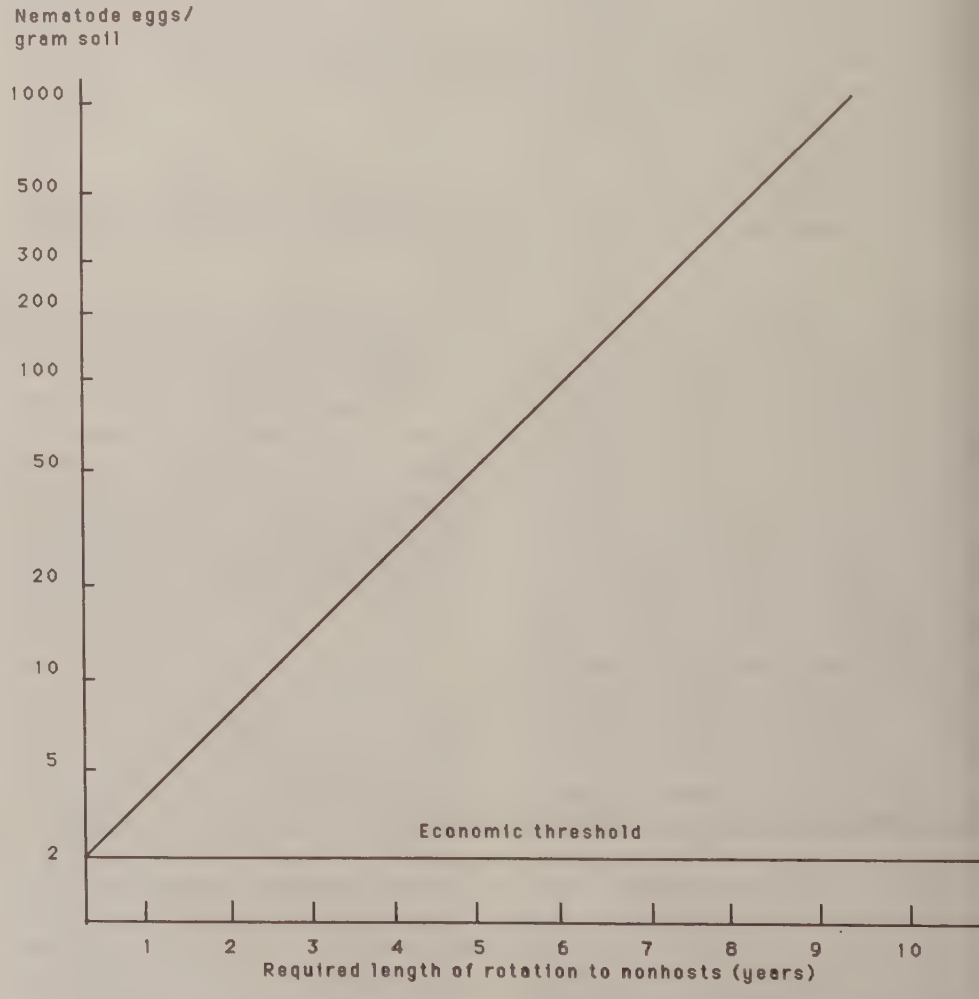

Figure 1. Scale for predicting rotation length needed to reduce sugarbeet cyst nematode population density to a level that will not cause economic damage to sugarbeets in the Imperial Valley of California (data from Roberts and Thomason, 1981).

crops and cultivars. These limitations are offset to some extent by the advantages of a rapid decline rate of root knot nematode population densities (80 to 90% or more annually) in most cases (Ferris, 1985) and the availability of resistant cultivars of certain crops. Recently, for instance, cultivars of processing tomato have become available that are highly resistant to the cotton root knot nematode, *M. incognita,* and some other root-knot species (Roberts and May, 1986). These cultivars can be grown in heavily infested ground, show little damage due to nematode tolerance, and prevent almost all reproduction by the nematode—allowing production of susceptible crops in the following year (Roberts et al., 1986). For example, research has shown that a one year rotation with a resistant processing tomato cultivar can be as effective as standard preplant fumigation with 1,3-Dichloropropene in reducing yield losses to root knot nematodes in a subsequent cotton crop. Similar results were obtained when resistant tomatoes were followed by susceptible lima beans (Roberts, unpublished data). Other rotations in California that aid in the management of the cotton root knot nematode include moderately resistant cowpea cv. California Blackeye 5 or nonhost alfalfa; however, the cowpea cultivar is not as effective as the highly resistant tomato cultivars in reducing populations (Duncan and Ferris, 1983; Roberts and May, 1986; UC Statewide IPM Project, 1984).

Managing adjacent lands: diversity over local areas

Some pests invade fields and orchards mostly from adjacent fields or uncultivated areas. These pests can disperse short distances but do not have a good mechanism for long distance dispersal. Significant damage does not occur commonly where the crop is located more than 1/4 mile (to a few miles in some cases) from a reservoir of the pest. The most common types of pests in this category include viruses and other diseases with sucking insect vectors and vertebrate pests that require adjacent uncultivated areas for nesting or shelter purposes. A few fairly host specific insects on perennial crops, such as the navel orangeworm (Engle and Barnes, 1983) in almonds and artichoke plume moth (Lange and Kishiyama, 1978) in artichokes, can be managed to some extent when cultural or other practices are undertaken that drastically reduce their numbers within the managed area. Three other examples of these kinds of management approaches are discussed here.

Pierce's disease of grapes: Pierce's disease of grapes, a bacterial disease spread by leafhoppers provides a vivid example of a pest problem that is associated with cropping patterns and vegetation in downwind adjacent areas (Purcell, 1981). The bacteria invade the xylem or water conducting vessels of the grape vine and infected vines look water stressed. Vines may take many years to die but production is reduced substantially within the first few years after infection. Although the disease is a problem both in the San Joaquin and Napa Valleys, the primary leafhopper vectors in the two areas and their preferred alternate hosts are different.

In the San Joaquin Valley, the green sharpshooter, *Draeculocephala minerva,* is the most important vector. It prefers to feed on weedy grasses, which also host the disease usually with few symptoms; the sharpshooter frequently moves in from old, grass-infested alfalfa fields, from orchards with a year round weedy ground cover (orchards that are thoroughly clean-cultivated once a year are not a problem) or from uncultivated areas. Even a relatively small area of grasses along a roadside or irrigation ditch can be the source of a damaging infestation. Management in this area of California focuses on removing old weedy alfalfa fields, controlling grassy weeds in new crops and on the vineyard floor, and in neighboring weedy areas. Research has shown that removing infected vines from the vineyard does not reduce spread within the vineyard because these are not the preferred hosts of the leafhopper.

In the Napa Valley, the common vector is the blue-green sharpshooter, *Graphocephala atropunctata,* which prefers woody, perennial bushy plants such as wild grape, blackberry, and elderberry and is most common along stream banks or ravines and canyons. Less susceptable grape varieties should be grown in vineyards planted near these areas.

Sugarbeet yellows: Another disease problem that is related to adjacent crops is the complex of three aphid transmitted viruses in sugarbeets, which is collectively referred to as sugarbeet yellows (Hills et al., 1982). The two most common are the beet yellows virus (BYV) and beet western yellows virus (BWYV). Another virus, beet mosaic virus (BMV) is also part of the complex but is less frequent and produces a mosaic pattern on the leaves. The pathogens cause particularly devastating losses if plants are infected when they are young. The disease infects new sugarbeet plantings when aphid vectors (primarily the green peach aphid, *Myzus persicae,* and the bean aphid, *Aphis fabae*) move into seedling fields from infected maturing sugarbeet fields. Research in the 1960s (Shepherd and Hills, 1970) showed that new seedling fields planted 10 to 20 miles from old plantings avoided economic losses, and a barrier of even 5 miles significantly improved production. To reduce the spread of the disease to newly planted beets, the California Beet Growers Association established districts across the state allowing overwintering of beets but no early spring plantings in some areas and requiring fall harvest but allowing early spring planting in others. These districts virtually eliminated the sugarbeet yellows problem for almost 15 years; however, recently the disease has begun to reoccur at economic levels. A change in aphid vectors, time of aphid flights, and a lack of adherence to district deadlines may be involved.

Border harvesting of alfalfa: Adjacent crops can have positive as well as negative effects on neighboring areas. A particularly well researched case is alfalfa, which as a lush and nutritious perennial provides an excellent habitat for many insects—both pest and beneficial. One of the most serious pests that builds up in alfalfa is the lygus bug, *Lygus hesperus,* a major pest in cotton and numerous fruit crops. Lygus, which does little economic damage to alfalfa grown for hay, will move to adjacent cotton

fields in great numbers when alfalfa hay is harvested, which may occur as often as once a month in the summer.

Growers and researchers over the years have experimented with various ways to prevent the migration of lygus into adjacent crops, particularly cotton, when alfalfa hay is harvested. The idea behind each scheme is to keep enough tall alfalfa in the area to prevent lygus from migrating out of the field. This can be done by staggering harvest schedules for adjacent alfalfa fields or halves of large alfalfa fields. It can also be done by following a strategy, called border harvesting, where a strip of unmowed hay, about 5 feet wide, is left along alternate borders of each check (Summers, 1975). At the next harvest, this remaining hay is mowed and the opposite border left standing. With this procedure less than 5% of the field is left unmowed at any harvest. Not only does the technique keep lygus from moving into other crops, it provides a refuge for the many natural enemies of insect pests that are found in typical alfalfa fields (Figure 2). These predators and parasites are extremely important in limiting numbers of alfalfa hay pests, especially aphids and armyworms, below economic levels. Many of the general predators that take refuge in alfalfa will move into neighboring fields of annual crops, providing them with a significant head start on biological control as compared to fields that have no ready source of overwintered natural enemies.

Intercropping: Diversity within the field

The concept of interplanting more than one crop in a field at the same time to reduce pest problems has received considerable attention in recent years (Andow et al., 1986; Altieri and Gliessman, 1983; Letourneau and Altieri, 1983; Risch et al., 1983). Intercropping is quite common in young orchards in California; however, the primary purpose has been to obtain economic production out of the land during the early unproductive years of tree development rather than pest management. Similarly, many young as well as mature orchards are maintained with ground covers (rather than crops) of seeded grasses, legumes, or weeds. Planting, mowing and maintenance of these ground covers is itself a form of weed control and has both positive and negative effects on other pests including insects, vertebrates, nematodes, and plant pathogens. The pest management implications of cover crops in orchards are complex and for the most part poorly understood.

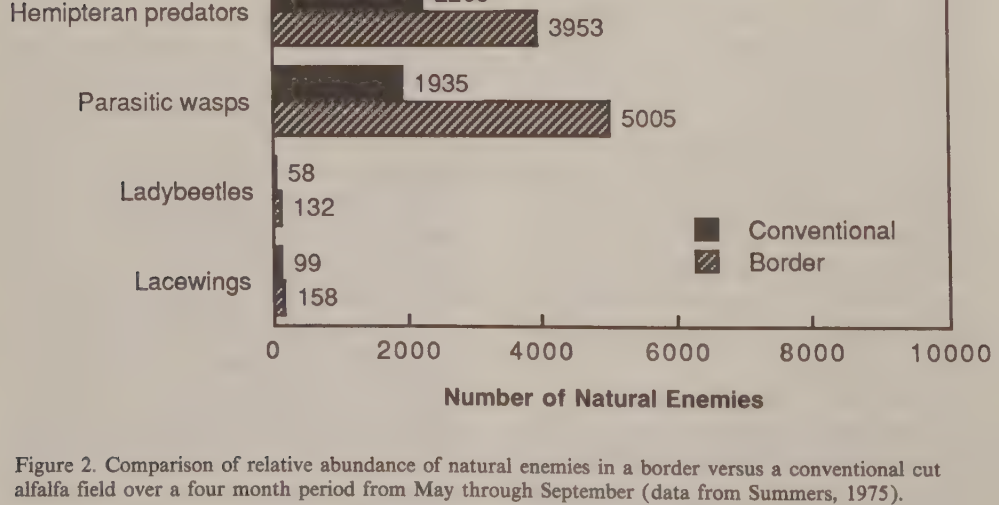

Figure 2. Comparison of relative abundance of natural enemies in a border versus a conventional cut alfalfa field over a four month period from May through September (data from Summers, 1975).

There are only a few examples of intercropping programs being used commercially on moderate to large scale farms in field crops in California. Two examples are given here to show possible benefits of intercropping for pest management in these types of crops.

Cotton intercropped with alfalfa: A previous example discussed the benefits of alfalfa adjacent to a cotton field for lygus bug management and increased biological control. The value of intercropping strips of alfalfa every 300 to 500 feet within the cotton field was demonstrated almost 20 years ago (Stern et al., 1969; Sevacherian and Stern, 1974). A very few California cotton growers use this technique to preserve natural enemies and keep lygus out of their cotton. However, management of the strips requires careful attention; they must be adequately irrigated and carefully managed for success with this approach.

Seedling alfalfa intercropped with oats: Various forms of intercropping have potential for improving weed control. Thirty or more years ago, California hay growers commonly seeded oats along with alfalfa to suppress weeds during stand establishment. Oats would be harvested with the first cutting, providing good forage and the remaining stubble would provide a type of mulch to repress weed growth until the alfalfa grew large enough to effectively outcompete the weeds. However, the advisability of this practice and precise recommendations on seed rates for both crops were never established. The practice was phased out as herbicides became available; now, however, with the cost of pesticides rising and increasing restrictions on herbicide use there is an increasing interest in intercropping for weed control in alfalfa. Current research (Lanini et al., 1987) showed intercropping to be a viable weed control practice particularly with today's short statured oat varieties, with intercropped plots out-yielding no oats plots in total forage during the first year and equal in alfalfa hay production by the final cutting of the first year. Recommendations are now being developed for seeding rates of oats and alfalfa for optimal use of this technique in California.

Conclusion

The strategy of using crop diversity to manage pest problems has potential value for the large, more specialized farm as well as the small, highly diversified, labor-intensive farm; this is especially true when diversification is viewed over time and on an area-wide basis—not just within a single field in a single growing season. Some larger farms in California have been managing problem pests through the diversification of their cropping systems for many years. However, growers must be strongly motivated to make the necessary changes in their cropping systems; it is probably no accident that the most widely adopted of the systems described here are for pests for which few other economically feasible methods were available. For instance, nematodes are prime targets for alternative strategies because many nematicides have been removed from the market in recent years. Insect vectored diseases such as Pierce's disease and sugarbeet yellows have always been difficult to control because even very low numbers of insects can spread the pathogens effectively enough to destroy the crop; disease resistant cultivars have been the primary management method for these problems, but resistant cultivars can be difficult and expensive to develop. On the other hand, the border harvesting of alfalfa and intercropping of alfalfa and cotton have not been widely adopted; insecticidal alternatives, which are easier to use, are available for the major pests managed with these methods.

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Illinois forms sustainable agriculture society

A new Illinois Sustainable Agriculture Society (ISAS) will provide farmers with information on environmentally sound, lower cost, profitable farming techniques, says Donn Klor, a Buffalo, Illinois, farmer recently elected President of the new group. ISAS also plans to conduct on-farm demonstration projects to look at fertilizer efficiency, low-cost weed control, and cover crops. The first issue of the ISAS newsletter (January 1989) gives a list of groups involved in sustainable, low-input agriculture and reviews useful literature. Membership is $10 per individual/family; $50 for businesses. For more information contact ISAS, c/o Donn Klor, RR #1, Box 58A, Buffalo, IL 62515.

On-farm experiment designs and implications for locating research sites

Phil E. Rzewnicki, Richard Thompson, Gary W. Lesoing, Roger W. Elmore, Charles A. Francis, Anne M. Parkhurst and Russell S. Moomaw

Abstract. *Research plots that are large enough to accommodate regular farm machinery are thought to contain too much field variation to allow reliable interpretation of experimental results. This study was conducted to determine whether experimental error was controlled on a wide variety of agricultural field trials that used plots larger than normally used by researchers. The investigation included trials conducted on an experiment station and trials conducted on actual commercial farms. The planning and management of the experiments ranged from those completely conducted by university researchers to those completely done by farmers.*

The level of experimental error in all the trials was well within the limits normally accepted by researchers in agronomy. Plots ranging in length from 125 to 1200 feet and as wide as one or two passes of standard farm machinery gave experimental results that were statistically sound. Statistical requirements for randomization and replication were all met.

The ability to use large plots and farmer participation enhances the testing of new technology on farms. This leads to new opportunities to test crop production factors in a systems setting under actual farm conditions. The statistical reliability of the on-farm designs analyzed in this study should increase cooperation among researchers, extension workers, and farmers in research activities.

Key words: research plot size, experimental error, actual commercial farms, randomization, replication, new technology, statistical reliability

Introduction

The use of working commercial farms as sites for conducting agricultural research is often not considered when experiments are planned. However, on-farm research can provide unique opportunities to answer some questions augmenting what can be done on experiment stations. Lockeretz (1987) provides the following reasons for considering on-farm research as a component of a balanced, overall agricultural research program:

—desired soil types or other physical conditions are not available on the experiment station but are available on farms;

—larger land areas are needed than those available on an experiment station;

—studies are needed of interactions among several enterprises within a farm system;

—constraints of a working farm are needed to compare the performance of a system there with its experiment station counterpart;

—techniques to be evaluated are particularly sensitive to levels of management such as integrated pest management;

—farm sites are available where a production method has been in use for a long time and the long-term effects of such a method are being researched.

Other specific reasons for selecting a research location on-farm include the need to test new techniques under a range of conditions or to analyze a problem found on an individual field. Current public concerns about environmental quality and renewed interest in the economic feasibility of farm production recommendations are broader reasons. Lastly, there is an increasing concern by university researchers and extension personnel about the need for a systems approach in developing new information and recommendations. Actual farm sites can provide some of the systems to test the applicability of new information found at experiment stations or to investigate new alternatives.

Much of the literature in recent years regarding on-farm research justification and methodology has been generated in the area of Farming Systems Research and Extension (FSR/E) (Gilbert et al. 1980). Evaluation of new technology with respect to profitability and compatibility of new input combinations with farmer systems is the final stage of agronomic testing in farm trials of major international research centers (Sanders and Lynam, 1982). High rates of adoption of recommended practices have been found when research is conducted on farmers' fields (Martinez and Arauz 1984). On-farm research in the international arena has not only accomplished evaluation and transfer of new technology, but has also generated new

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technology as researchers learn of the benefits of practices developed by farmers (Horton, 1984). Models for defining the functions of researchers, extension workers and farmers in on-farm research have been developed (Kirkby, 1984; Hildebrand and Poey, 1985). Criteria have been devised for categorizing new extension recommendations by types of farmers or recommendation domains as a result of on-farm research (Byerlee et al., 1980).

On-farm research in the U.S.A

In the United States researchers conduct some on-farm research. These trials usually use small plots and specialized equipment and/or hand planting and harvesting. The researcher provides nearly all the planning and management of the on-farm experiment using the same techniques as applied in experiment station trials. However, new research demands for testing within farm systems or incorporating farmer management requires large tracts of land, increased farmer cooperation and an in-depth look at the objectives of an experiment and treatment numbers. Also, farmers more readily believe results from plots on which full sized farm machinery can be used. Some farmers are skeptical about results which come from small plots in conventional experiment station field trials (Francis et al., 1986; Thompson, 1986).

If on-farm research involves conventional farm machinery and large plots, a small number of treatments is recommended. With farm strip plots, the optimum number of treatments is 2 to 5 (Havlin and Elmore, 1984). Replicates are necessary to provide an estimate of the experimental error. Using large plots does not reduce the number of replicates needed to achieve research requirements. If replication cannot be achieved on a farm site, it can be obtained if a number of farms are used with the same treatments applied to all farms.

The objective of this study was to show that experimental error can be controlled in agronomic field experiments using research plots that are larger than conventional experiment station plots. Good statistical rigor can be achieved for a number of types of trials which use large plots or long strip plots.

Measuring experimental error

The coefficient of variation (CV) indicates the degree of precision with which treatments are compared and is used by experimenters to evaluate results from different experiments involving the same character, possibly conducted by different persons (Steel and Torrie, 1980). It expresses the experimental error as a percentage of the mean:

$$CV = \frac{SD}{\bar{X}} \times 100$$

where SD = standard deviation of the experimental data

$\bar{X}$ = grand or overall mean of experiment

The higher the CV value, the lower is the ability of the experiment to predict with a given certainty or probability that treatment effects are real and not due to chance alone. To know whether or not a particular CV is unusually large or small requires past experience with similar treatments. Researchers make judgments on the acceptability of an experiment based on CV's from other experiments in their subject matter area. For example, research experience with transplanted rice at the International Rice Research Institute indicates that for rice yield data, the maximum acceptable level of CV is 6% to 8% for variety trials, 10% to 12% for fertilizer trials, and 13% to 15% for insecticide and herbicide trials (Gomez and Gomez, 1984). The CV for yield usually differs from that for other plant response variables. For example, in a field experiment where rice yield CV is about 10%, that for tiller number would be about 20% and for plant height about 3%. Coefficients of variation for yield in irrigated corn hybrid trials in south central Nebraska on standard experiment station trials are in the range of 8% to 15% with SD = 15 to 23 bushels per acre. For irrigated soybean variety trials at the same experiment station, CV's are 6 to 12% with SD = 3 to 6 bushels per acre.

Analysis of variance for split-plot experiments will result in two coefficients of variation. If two treatment factors are labeled A and B with A being the whole plot factor and B being the split-plot factor randomized within whole plots of A, then the analysis of variance table would appear as follows for a randomized complete block experiment using a split-plot treatment design:

Source of variation	Degrees of freedom
Blocks	r-1
Factor A	a-1
Error (A)	(a-1)(r-1)
Factor B	b-1
A × B	(a-1) (b-1)
Error (B)	a(r-1) (b-1)

Coefficients of Variability

$$CV(A) = \frac{\sqrt{\text{mean square error (A)}/b}}{\text{grand mean}} \times 100$$

$$CV(B) = \frac{\sqrt{\text{mean square error (B)}}}{\text{grand mean}} \times 100$$

where: r = number of blocks,
a = number of levels of A,
b = number of levels of B,
error (A) = whole plot error, and
error (B) = subplot error.

The CV for factor A is the equivalent of ignoring the split-plot division and analyzing only whole plot values (Steel and Torrie, 1980). The value of CV(A) indicates the degree of precision attached to the whole plot factor A. The value of CV(B) indicates the degree of precision of the split-plot factor B and its interaction with factor A.

Large plots on experiment stations

Experiments using large plots have been conducted with rotations, relay planting and crop planting dates at the University of Nebraska Agricultural Research and Development Center (ARDC) in Eastern Nebraska. Characteristics of these experiments are summarized in Tables 1 and 2. The trials are all designed as randomized complete blocks using a split-plot treatment design. Although these trials were conducted on an experiment station, the plots were large and standard farm machinery was used. The ARDC trials provide examples for determining the

Table 1. Dryland corn yields and coefficients of variation for ten years in long-term rotation trial (oats/clover-corn-soybeans-corn) using large plots at ARDC, Mead, Nebraska.[1]

Yield grand mean (bu/acre)		Coefficient of variation[2]		Yield grand mean (bu/acre)		Coefficient of variation[2]	
1976	51	CV(A)	16.0	1982	98	CV(A)	4.1
		CV(B)	26.2			CV(B)	6.3
1977	25	CV(A)	29.4	1983	48	CV(A)	34.5
		CV(B)	19.7			CV(B)	17.3
1978	135	CV(A)	3.3	1984	62	CV(A)	6.3
		CV(B)	5.7			CV(B)	7.6
1980[3]	74	CV(A)	11.6	1985	113	CV(A)	6.2
		CV(B)	12.9			CV(B)	5.8
1981	111	CV(A)	6.8	1986	108	CV(A)	2.7
		CV(B)	13.0			CV(B)	5.3

[1] Plot size 40′ (16 rows) x 125′, randomized complete block of 3 whole plot treatments with 2 split-plot treatments, 4 replications and 24 plots. Whole plot treatments are three cropping systems (organic or manure only, fertilizer only, and fertilizer plus herbicide). Split-plot treatment is the effect of the previous crop (oats/clover or soybeans) on corn yield.

[2] $CV(A) = \frac{\sqrt{\text{mean square error (A)}/2}}{\text{grand mean}} (100)$

$CV(B) = \frac{\sqrt{\text{mean square error (B)}}}{\text{grand mean}} (100)$

[3] 1979 data on corn yield as affected by split-plot factor unavailable.

Table 2. Soybean, wheat and corn yields and coefficients of variation in relay cropping trials (1986) and planting date trials (1987) using large plots at ARDC, Mead, Nebraska.[1]

Experiment type	Plot size	No. of whole plot treatments	No. of split-plot treatments	Crop	Yield grand mean (bu/acre)	Coefficient of variation[2]	
Relay cropping soybeans and wheat	20′ x 200′	3 soybean varieties dryland	3 planting dates	Soybeans	29	CV(A)	4.7
						CV(B)	10.0
				Wheat	30	CV(A)	9.4
						CV(B)	7.8
Relay cropping soybeans and wheat	20′ x 200′	3 soybean varieties irrigated	3 planting dates	Soybeans	25	CV(A)	7.8
						CV(B)	15.2
				Wheat	32	CV(A)	4.7
						CV(B)	4.5
Soybean planting dates	30′ x 800′	3 planting dates	3 soybean varieties	Soybeans	33	CV(A)	9.0
						CV(B)	7.5
Corn planting dates	30′ x 160′	3 planting dates	3 corn varieties	Corn	121	CV(A)	12.7
						CV(B)	10.2

[1] Randomized complete blocks with split-plot treatments; 4 replications and 36 plots in relay cropping trials; 3 replications and 27 plots in planting date trials.

[2] $CV(A) = \frac{\sqrt{\text{mean square error (A)}/3}}{\text{grand mean}} (100)$

$CV(B) = \frac{\sqrt{\text{mean square error (B)}}}{\text{grand mean}} (100)$

reliability of such plots for precise experimentation.

A four-year rotation (oats/clover-corn-soybeans-corn) had three whole plot treatments (organic, i.e., manure only, fertilizer only, and fertilizer plus herbicide). The split-plot factor was the effect of the previous crop (oats/clover or soybeans) on corn yield. Plot size was 40′ x 125′. The coefficients of variation for the first two years, 1976-1977, are high (Table 1). This is attributed to initial adjustment of the plots to the rotation treatment combinations. From 1978 to 1986 coefficients of variation are within the ranges normally experienced in agronomic research except for 1983 which was a year of very dry conditions and low, variable yields. Mean yields in years 1978 to 1986 were consistent with corn yields in the region.

Four experiments using narrower and longer plots are summarized in Table 2. The soybean planting date trial with three varieties of soybeans used plots that were more than a half acre each and 4 to 6 times longer than those in the other trials, yet experimental error is still within acceptable limits. Coefficients of variation in these experiments ranged from 4.5 to 15.2 percent, with yields comparable to commercial fields on the station and nearby farms in 1987. Although it is not the purpose of this study to examine treatment differences, it is noteworthy that significant differences among treatment means were found at a 5% level of significance in analyzing the variance of nearly all these large plot trials. Results from these experiments at ARDC suggest that large plots and standard designs can provide credible information on agronomic questions using full size equipment and other commercial practices.

Field length on-farm plots

An innovative farmer group called The Practical Farmers of Iowa (PFI) has organized a program for on-farm research with an understanding of the need for sound experimental design. Usual PFI plot size is 8 rows wide by 1200 feet long. The number of treatments is usually fixed at 2 with 6 to 8 replications. The experimental design is a randomized complete block. The long, narrow strips are randomized side by side within a block. Blocks are adjacent to each other in the same field.

Strip plot width, usually eight rows depending on equipment width, allows for one round of planting and harvesting with 4-row equipment. When the field

is not in a ridge-till or permanent row system, the PFI group uses border rows with a strip plot width of sixteen rows. Only the center eight rows are harvested for test data.

The permanent rows of a ridge-till field facilitate test plot layout. There is no cross tillage that would spread previously applied materials from one treatment plot to another. Experimental treatment factors can be applied precisely over the permanent rows.

An ACU electronic grain monitor is used for weighing the grain combined from each strip plot in each field.[1] The Iowa farmers were concerned about the accuracy of the grain monitor for weighing only 30 to 35 bushels of soybeans from each strip plot. PFI compared the ACU readings for 31 plots of soybeans with the readings of an electronic weigh scale. The ACU monitor was consistently within 1.6% of the electronic weigh scale.

The characteristics and coefficients of variation of 23 trials conducted on 9 farms in 1987 are outlined in Table 3. The experiments are categorized by treatments, including N fertilizer levels or sources, starter fertilizer levels or sources, herbicide levels, varieties, tillage practices, or different planters. With corn and soybean yields that are typical for central Iowa, the coefficients of variation are exceptionally low. The level of experimental error in these trials should be very acceptable to researchers in agronomy. The design with narrower strip plots and more replicates than used in the large plots reported in Tables 1 and 2 appears to reduce even further the level of random variation.

Blocking in the analysis of variance (not shown) reduced the error of nearly half of the PFI trials (alpha = .05). The use of randomized complete block design as opposed to a completely random design should be considered a standard recommendation to reduce experimental error when on-farm research trials are planned.

All the PFI trials were sensitive enough or had enough power to detect significant differences between treatment means at alpha = .05. A more detailed discussion on power of experimental designs will follow later. Most of the Iowa experiments tested the effect of using lower fertilizer or chemical inputs or no chemicals whatever. In nearly all these trials, higher levels of inputs provided no significant difference in yield. The experiments as conducted gave the Iowa farmers confidence in the results and a willingness to apply the knowledge gained to their future management.

Table 3. Yields and coefficients of variation from corn and soybean on-farm trials of the Practical Farmers of Iowa on 9 farms, 1987.[1]

Farm No.	Experimental treatments	No. of replicates	Yield grand mean (bu/acre)	Coefficient of variation
Crop: Corn				
1	2 N fertilizer levels or sources	6	137	1.6
1	2 N fertilizer levels or sources	6	112	3.5
1	2 N fertilizer levels or sources	4	123	1.7
2	2 N fertilizer levels or sources	4	179	0.7
3	2 N fertilizer levels or sources	6	146	2.7
4	2 N fertilizer levels or sources	5	173	3.7
5	2 N fertilizer levels or sources	6	172	1.7
6	2 N fertilizer levels or sources	6	137	1.9
8	2 N fertilizer levels or sources	6	88	2.5
1	2 starter fert. levels or sources	6	120	5.0
1	2 starter fert. levels or sources	6	128	4.6
1	2 starter fert. levels or sources	6	109	3.4
1	2 starter fert. levels or sources	4	127	0.7
7	2 starter fert. levels or sources	6	117	2.2
1	2 herbicide levels	4	120	2.8
3	2 herbicide levels	6	135	3.1
9	2 herbicide levels	6	120	2.2
1	3 varieties	5	140	3.2
6	2 tillage systems	6	135	5.9
Crop: Soybeans				
1	3 potash fert. sources	8	51	2.9
4	2 herbicide levels	6	55	2.0
1	2 planters	6	52	1.6
1	2 planters	7	54	2.1

[1] All plots 1200′ long; widths varied from 4 rows to 12 rows with majority at 8 rows; row width for any one farm was 30″, 36″, 37″, or 38″.

Replication by farm

The area needed for each experiment for the type of on-farm design used by the PFI ranges from 8 acres without border rows to 16 acres with border rows. If farmers involved with on-farm research do not want to dedicate that amount of land to an experiment or if more treatments are included, the necessary replications can be attained by testing the same treatments on a number of farms. Using farms as blocks, experimental error is based on the variation among experimental units within a block after adjustment for any observed, overall treatment effect.

Two types of studies conducted by University of Nebraska faculty in cooperation with farmers utilized replication by farm. Both used large plots and offered some control of random variation within each farm.

Four farms in three counties of Northeast Nebraska were used to test narrow (15 inch) and conventional (38 to 40 inch) row spacings in soybeans (Moomaw, 1978). The average length of the on-farm test plots ranged from 250 to 400 feet. Plot width for each row spacing was one round with the planting equipment (approx. 25 to 30 feet). Some control of experimental error on each farm was attained by conducting at least two or three replications per row spacing on each farm. Analyzing the experimen-

[1]Mention of a brand name or trademark does not constitute endorsement of this product by the University of Nebraska, the authors or the publisher.

Table 4. Corn yields and coefficients of variation in four years of variety performance trials using replication by farm, Clay County, Nebraska.

Year	No. of varieties	No. of replicates	Yield grand mean (bu/acre)	Coefficient of variation
1984	13	3	173.7	4.0
1985	20	4	177.8	3.4
1986	19	4	172.0	3.7
1987	22	3	174.3	3.4

tal data with the four farms treated as blocks in a randomized complete block design, the coefficient of variation was 7.8% with SD = 3.5 bushels. Soybean yield for the conventional row spacing was significantly lower (alpha = .05) than the narrow row spacing (conventional 43.2 bu/acre, narrow 47.1).

In south central Nebraska, the Clay County Corn Growers Association is cooperating with extension personnel in testing the performance of corn varieties under irrigation. Table 4 is a summary of the coefficients of variation found by using three or four farms each year as the replications. Plots were in the same size range as used by the Practical Farmers of Iowa. Strip plots 6 or 8 rows wide (15 to 20 feet) by field length (1200 to 1300 feet) were used. On each farm, the crop varieties were managed the same way as the cooperator managed the remaining part of the field. Only one plot of each variety is used on each farm. The location of each variety on each farm is randomly selected.

A common check variety was used after every third variety in these Clay County trials. The average of the check variety on each farm was calculated and a weighted factor based on the check plots on either side of the test variety was then used to arrive at the adjusted yield for each variety on each farm. Using check varieties removes some of the yield variability due to location within a field; therefore, some control of experimental error is obtained even with a high number of treatments. The check variety should be one that has a yield record similar to the other varieties (Elmore, 1986).

On-farm variety performance trials with CV's of 3.4 to 4.0 percent were at least as reliable as the experiment station variety trials in the same geographic location. Coefficients of variation of 8% to 15% reported earlier for south central Nebraska were for experiment station corn performance trials conducted on 120 varieties.

Power of on-farm designs

Agricultural researchers are familiar with coefficients of variation and experimental error. But for most farmers, such statistical terminology may be meaningless. Producers can appreciate differences in yield, so it is of interest to discuss the statistical concept called power. In its simplest form, power is defined as the probability that an experiment can detect the true differences between two treatment means. For example, if one level of nitrogen fertilizer "truly" produces 95 bushel corn and another level of that fertilizer "truly" produces 105 bushel corn, power is the probability that one experiment will detect this "true" 10 bushel difference. The "true" yields in this case are the average values one would measure if an infinite number of trials were conducted under the same conditions.

Table 5 is an abbreviated look at the power of using a randomized complete block design for detecting differences between treatment means at the 5% significance level when the true difference between two treatments is 5%, 10%, and 20% of the overall mean. At a fixed probability level of significance, power is increased by an increase in sample size, a reduction in uncontrolled variance, or an increase in the magnitude of the treatment effects. Calculations of power for Table 5 were performed using Statistical Analysis System (SAS) computer software (SAS Institute Inc., 1982; detailed information on determining power with SAS is given in O'Brien (1984).)

Most agronomy researchers attempt to find an experimental design that has a minimum of 80% power. In this study, we have found that experimental designs such as those used by the Practical Farmers of Iowa using long, narrow strips and six replications had a 79% to 99% probability of detecting a difference of 10%; for example, 45 bushel soybean versus 50 bushel soybean with a SD of 1.2 to 2.4 bushels or 95 bushel corn versus 105 bushel corn with a SD of 2.5 to 5.0 bushels. If coefficients of variation are as high as 10%, the probabilities of detecting a difference of 5% or 10% are very low and it takes at least 6 or 7 replications to detect a difference of 20% with acceptable power.

The power of an experimental design can lead to economic evaluation of new technology. During the planning of an on-farm trial, cooperators should ask what amount of true differences between treatment means would influence them to adopt or reject a particular treatment factor. An experiment may establish a difference of 5 bushels of corn between two treatment means as significant, but is this difference important? Deciding what difference is important would provide a guideline to the number of replications needed based on previous experience on other farms with similar designs, treatments and resulting experimental error.

Discussion and conclusions

On-farm research designs using large plots that range in length from 125 to 1200 feet can provide reliable agronomic

Table 5. Power (%) of a randomized complete block design for 5% level of significance.

No. of replicates	difference[1] = 20%			difference = 10%			difference = 5%		
	CV 2.5%	CV 5.0%	CV 10.0%	CV 2.5%	CV 5.0%	CV 10.0%	CV 2.5%	CV 5.0%	CV 10.0%
3	99%	70%	29%	71%	29%	11%	29%	12%	7%
4	99	95	49	95	49	17	49	17	8
5	99	99	66	99	66	23	66	23	9
6	99	99	79	99	79	29	79	29	11
7	99	99	87	99	87	35	87	35	12

[1] Difference between two treatment means expressed as percentage of overall mean.

data from research experiments, with experimental error controlled for a wide variety of agricultural factors. If only two or three levels of inputs are compared, long strip plots 8 rows wide can be planted, maintained and harvested by farmers with little or no assistance by researchers or local extension personnel. More complex on-farm designs such as split-plots or factorials would require more researcher input, at least in the designing phase. However, farmer's equipment and management skills can easily and reliably be used. Models for design and analysis could be generated that would allow farmers to conduct such trials and evaluate the results.

If a producer wants to cooperate but cannot dedicate enough acreage for the replications needed, then replications of the same treatments can be performed on the farms of other cooperators. Another reason for replicating by farms is to verify the application of new technology over a range of conditions or a geographic area.

Further research is needed on the contribution of soil variability to the experimental error of the large plots tested. Our results show that field variation is well controlled with the use of narrow strips approximately 8 rows wide. As plots are widened, more experimental error is encountered; however, in the trials of this study, cv's of these wider plots were still within acceptable limits for agronomic research. It may be possible to determine the degree to which soil conditions have to differ to affect the precision of an experiment. Soil series and erosion classes could be studied as treatment factors in an analysis of variance (Olson and Nizeyimana, 1988). The interactions of these soil conditions with agronomic treatment factors of interest could also be investigated.

The statistical reliability of the on-farm designs analyzed in this study should enhance the development of models for integrating research activities of farmers, extension personnel and researchers. Approaches can be explored involving farmers, extension agents and researchers in a stepwise research process, from identification of problems to field experimentation to analysis and interpretation of results. This would make the greatest possible use of ideas from the entire group (Francis, 1986).

In 1988, the University of Nebraska initiated two projects that require the cooperation of many farmers, agricultural extension agents and researchers. Both projects will last for three years. Field plots have been designed on the farms of nineteen cooperators out of a targeted total of twenty-four to compare crop rotation systems to the farmers' current practices. Fourteen cooperators out of a targeted total of thirty are comparing relay cropping and strip crop systems to their current practices. These projects and other on-farm research activities should begin to provide us with information for refining models for farmer-extension-researcher cooperation.

As these models are developed for practical applications in agriculture, guidelines for each participant can be defined. Farmers will be better able to understand the importance of reliable experimental design and to participate in the analysis of data. Extension workers can provide season-long observation and management assistance to assure that experimental plots are treated alike except for the treatment factors of interest. Researchers can learn new ways of incorporating problems identified by farmers and extension agents into their research agenda which will help them gain respect and credibility from the ultimate users of their research efforts. We propose an expanded involvement of research and extension specialists with farmers in a cooperative on-farm research venture to provide practical results for tomorrow's agriculture.

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COMMENTARY

Open questions in sustainable agriculture

William Lockeretz

Key words: organic soil amendments, crop rotation, pesticides, farm income, environmental pollution, organic farming, resource conservation, alternative agriculture, low-input agriculture

The concept of sustainable agriculture

"Sustainable agriculture" is a loosely defined term for a range of strategies to cope with several agriculturally related problems causing increasing concern in the U.S. and around the world. Notable among these problems are the contamination of the environment by pesticides, plant nutrients, and sediments; loss of soil and degradation of soil quality; vulnerability to shortages of nonrenewable resources, such as fossil energy; and most recently the low farm income resulting from depressed commodity prices in the face of high production costs. Sustainable agriculture is based on several general concepts (Hodges, 1982; Harwood, 1985; Francis et al., 1986; Madden, 1987; Francis and King, 1988):

1. Diversity of crop species to enhance the farm's biological and economic stability, such as through rotations, relay cropping, and intercropping;

2. Selection of crop varieties and livestock that are well suited to the farm's soil and climate, and that resist pests and diseases;

3. Preference for farm-generated resources over purchased materials, and for locally available off-farm inputs, when required, over those from remote regions;

4. Tightening of nutrient cycles to minimize loss of nutrients off the farm, such as by composting of livestock manures and by rotations using legumes to fix nitrogen;

5. Livestock housed and grazed at low density, with preference for high roughage rations over concentrated feeds for ruminants, and with herd size scaled to the farm's ability to produce feeds and use livestock manure efficiently;

6. Enhancement of the soil's ability to take up applied nutrients for later release as needed by the crop, in contrast to direct uptake by the crop at the time of application;

7. Maintenance of protective cover on the soil throughout the year, through tillage that leaves crop residues on the surface, and through cover crops and living mulches;

8. Rotations that include deep-rooted crops to tap nutrient reserves in lower strata, and that control weeds by alternating between cool season and warm season crops;

9. Use of soluble inorganic fertilizers, if at all, only at a level that the crop can use efficiently, and only to the extent that nutrient deficits cannot be met first by livestock manures and legumes;

10. Enhancement of conditions for controlling or suppressing weeds, insect pests, and diseases, with synthetic insecticides and herbicides used, if at all, only as a last resort and only when there is a clear threat to the crop.

Evolution and current status of the concept

Sustainable agriculture's principles and techniques come from many sources, some recent, some going back several decades. It clearly owes an important debt to organic farming, a term that came into use sometime before World War II, although its originator is not known (Robert Rodale, private communication). Initially, organic farming emphasized recycling of farm-generated nutrient sources and discouraged bringing in nutrients in the form of livestock feeds and chemically processed fertilizers (Scofield, 1986). Today the term particularly emphasizes avoidance of synthetic pesticides.

Recently, this approach has evolved into a more general concept, variously labelled "sustainable agriculture" or any of several related terms (as discussed later). This evolution has come about as a broader range of people have become interested in the same goals for diverse reasons. The depressed farm economy has caused a shift in emphasis from "maximum production" to "optimal production," the idea being that a sys-

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tem should be evaluated not simply by how much it produces, but rather by the relative value of what comes out compared to what goes in. This has given rise to the concept of "low input" agriculture, a reversal of a long-standing trend towards greater production through greater use of purchased inputs. In the United States we tend to think of this term as applying only to cultivated crops. However, it is equally applicable to pastures and forages, especially in Western Europe, for example, where conventional grassland management often involves a high level of inputs (Wagstaff, 1987).

Often, the inputs that farmers can cut back on to save money also are environmentally damaging or hazardous to health. Thus the trend towards "low input" agriculture can help meet other important goals that have become more prominent in recent years, such as avoiding further contamination of ground water by pesticides (Hallberg, 1986), and meeting consumers' growing demand for healthful, uncontaminated foods (Clancy, 1986). These issues have led to much greater interest in sustainable agriculture, but even its most basic ideas remain to be worked out, not just specific questions of technique. Although the term is singular in form, "sustainable agriculture" really denotes a multi-dimensional concept, and it is not surprising that no single view of it has so far gained universal acceptance.

It therefore is important to keep in mind the many fundamental questions that still need to be discussed, analyzed, and debated before we can know what "sustainable agriculture" really means. Some of these questions may never be answered, but sometimes they aren't even asked, or the answers are asserted rather than demonstrated. Until these questions are discussed explicitly, we cannot know whether we are using the same words to mean different things, whether a particular approach can simultaneously serve the several different goals we would like it to achieve, or even whether there might not be intrinsic contradictions among the various goals that have been thrown together under the single umbrella term "sustainable agriculture." Nor will we know the best economic, institutional, and political environment to allow sustainable agriculture to fulfill its potential.

Fundamental questions

What are the differences between "sustainable," "alternative," "low input," "ecological," and "regenerative" agriculture?

In the past decade all these terms, plus several less common ones, have come into use as labels for agricultural systems that share basic goals: reduced use of purchased inputs, especially toxic or non-renewable ones; less damage to the environment; and better protection of water, soil, and wildlife. But both the technical and popular literature are unclear about the exact connotations of these terms.

Sometimes they appear to be used synonymously, or almost so (Merrill, 1983). For example, a recent article published by the U.S. Department of Agriculture, Economic Research Service (1988) began by talking about "'alternative agriculture,' also known as 'sustainable,' 'regenerative,' 'organic,' or 'low-input' agriculture." Other authors emphasize the differences among these terms. If defined according to everyday usage, these terms would have clearly differentiated meanings:

-- "Sustainable" has a time dimension and implies the ability to endure indefinitely, perhaps with appropriate evolution.

-- "Alternative" describes something that is different from the prevailing, or "conventional" situation. Another implication of the word is that farmers should be able to choose among alternatives, or options, rather than having to follow a single prescription.

-- "Low input" refers to reduced use of materials from outside.

-- "Ecological" refers to the principles and processes that govern the natural environment.

-- "Regenerative" implies the ability to recreate the resources that the system requires.

But regardless of their literal meanings, what about their meanings as actually applied to agriculture? All these terms have acquired further connotations, and some have become almost like brand names. Thus "alternative agriculture" does not mean simply "a different kind of agriculture." It must be different in a certain way. But in precisely what way? By being more sustainable? Ideally yes, but the way these terms are now used, it is not clear. For even though they carry specific implications when used in agriculture, terms like "sustainable" paradoxically have also come to be used in so many different ways by different groups that they seem in danger of losing any real meaning.

What can we conclude from this semantic confusion, these ambiguities, this proliferation of labels that may or may not mean the same thing? At a recent conference on sustainable agriculture, I noted that many speakers felt it necessary to introduce their talks by giving their definition of the word "sustainability." Isn't something backwards here? It seems curious that a term is considered important (or at least that it is considered important enough to be the theme of a conference) even though we don't know what it means. Perhaps, as Buttel (private communication) has suggested, sustainable agriculture "remains a solution in search of problems."

Less pessimistically, there are three possibilities, of which two are mainly semantic problems. The first is that several fundamentally different concepts are involved, but authors are not always careful about choosing the most appropriate term. Thus we really do need several labels, but imprecise usage has resulted in the impression that these labels are more or less interchangeable.

Conversely, a second possibility is that, when applied to agriculture, all these words basically are referring to the same concept; they may have proliferated because each was put forth by someone who believed that the previous terms did not capture that concept accurately, or who for some other reason chose to shy away from an earlier term. For example, "organic" apparently is thought by some people to suffer from a negative image. That may be why an article that quoted verbatim the U.S. Department of Agriculture's oft-cited def-

inition of organic farming never actually used the "O word," but instead claimed that "the U.S. Department of Agriculture defines *alternative farming* as follows" (Popkin, 1988 [emphasis added]).

A third possibility is more substantive: whether these terms are interchangeable might depend on the context, such as whether one is talking about broad principles or specific practices. Perhaps the basic concepts implied by these various terms are different. But when it comes to illustrating them by specific systems, everyone seems to end up using the same examples. For example, the first study of commercial organic farming in the United States (Lockeretz et al., 1981) only used the term "organic," and required only that the study farms not use synthetic pesticides and inorganic fertilizers. However, this same study has since been cited as dealing with "low input," "sustainable," and "ecological" agriculture.

This is fine as long as a given production system indeed embodies several of these general concepts. But the confused semantic situation could reflect a more serious problem: people may assume, rather than demonstrate, that a given agricultural system can simultaneously fulfill several different goals and embody several different agricultural ideals. Actually, it is necessary to demonstrate that it even achieves its stated, primary goal. Does calling a system "sustainable" guarantee that it is sustainable? And if it is "sustainable" -- that is, capable of enduring -- is it necessarily "alternative" -- meaning different from prevailing practices? Is an agricultural system that does not use so many inputs necessarily "ecological," that is, more like a natural ecosystem? In much of the literature, there is an implicit assumption that when one strives for any of these goals the others somehow come along automatically. There is little recognition that these goals are substantially distinct and independent, so that each has to be achieved in its own right. And rarely is it acknowledged that in designing specific production systems, rather than talking about abstract concepts, there can be incompatibilities that actually make it impossible to achieve them all (Lockeretz, 1986).

Is sustainable agriculture primarily a matter of reducing certain inputs, or reducing inputs in general, or instituting positive practices that make some inputs unnecessary?

The common identification of "low input" with "sustainable" agriculture raises some important questions. Organic farming, a precursor of sustainable agriculture, avoids or greatly reduces the use of two important categories of purchased inputs, namely synthetic pesticides and highly soluble inorganic fertilizers. The reasons for this involve soil productivity, the environment, and other biological and chemical considerations. An additional consequence is that organic farmers may have lower cash operating expenses (Lockeretz et al., 1981).

More recently, the idea of eliminating certain inputs regarded as particularly objectionable has been extended to reducing purchased inputs in general, to the extent feasible. This extension has been motivated by the depressed economic conditions affecting much of American agriculture, which could be ameliorated by reducing operating expenses. Another school of thought, more related to the original idea of organic farming mentioned earlier, is that a farm should strive for self-sufficiency as an end in itself, not just because a particular input is either damaging or expensive. In this view, the mere fact of being tied to another region or another sector of the economy can cause problems. (Interestingly, Rodale (1988) extends the distinction between a farm's internal and external resources -- a key element in the concept of "regenerative agriculture," of which he is the leading exponent -- even to management decisions, although most authors confine themselves to physical and biological inputs.)

Another view of the question of whether reducing inputs is intrinsically desirable is that sustainable agricultural systems should be based on positive steps that enhance soil fertility, control pests, and perform the many other functions that in conventional systems are largely performed by purchased inputs. Merely doing without such inputs is not an end in itself; the goal is to develop a system in which they would not be needed anyway. This concept emphasizes nutrient cycling, natural pest controls, diversity, continuous protection of the soil by living crops or residues, and wholesome housing and rations for livestock.

Interesting in this regard is the current use of the word "organic," once regarded as the narrowest and most proscriptive (i.e., "thou shalt not") of the terms under discussion here. The International Federation of Organic Agriculture Movements (1988), the only organization with sufficient status to presume to speak authoritatively on such matters internationally, begins its proposed technical standards for organic production with eight positive goals, ranging from high nutritional quality to maintenance of genetic diversity, to a decent return for farm workers. The standards go on to say that if techniques are chosen that will approach these goals, they will "make it possible to avoid...chemical fertilizers, pesticides, and other chemicals."

The differences among these attitudes towards reducing inputs is not academic nit-picking. Organic farmers in the narrower sense of the term -- those who do not use certain forbidden materials -- do not automatically try to cut down on their use of inputs in general (Wernick and Lockeretz, 1977). In fact, they may compensate by increasing their use of certain other inputs. For example, controlling weeds mechanically instead of with herbicides requires additional implements and fuel, as does applying manure rather than concentrated fertilizers. Some organic farmers buy organic fertilizer materials, which typically are more expensive than the same nutrients in inorganic form (Wernick and Lockeretz, 1977). If non-chemical pest control requires hiring professional scouts, then one expense (a service) is being substituted for another (a material). By environmental criteria, scouting is certainly preferable, but economically it could go either way.

In response to economic pressures some farmers have been cutting back on pesticides and fertilizers, as well as other inputs, without doing anything else differently. According to one view, this

qualifies as "sustainable." For example, the Wisconsin Rural Development Center (1988) puts the matter very simply: "Sustainable methods are those that use less commercial fertilizer, herbicide and pesticide." In some systems, such as dryland wheat in the Great Plains without herbicide-based chemical fallowing, pesticides and fertilizers have not been very important all along. Is this system sustainable? The Dust Bowl demonstrates that it isn't (Lockeretz, 1978). Is it organic? This system would come close to qualifying for certification as organic by several U.S. organizations (but not according to the proposed IFOAM standards), since certification programs generally emphasize what must not be done, and only secondarily mention what should be done. Is it the best possible system from the viewpoints of environment and resources? Probably not. Other systems could do more to enhance soil productivity, reduce erosion, preserve wildlife habitat, and increase economic returns, while continuing to avoid the materials considered undesirable. And this monocultural system certainly does not qualify as "ecological," since it hardly reflects the complex ecological structure of the shortgrass prairie it replaced.

Another interesting contradiction arises if a farm changes its fertilization system only because it happens to be near a source of organic wastes that can be substituted for purchased inorganic fertilizer. Such a farm fulfills one requirement of sustainability, in that it avoids using a material that is nonrenewable and potentially damaging to the environment. (Of course the wastes must be applied in an environmentally suitable manner, or they will create just as much of a problem.) However, it is not a "low input" system; only the form of the input is changed. Therefore it is as vulnerable to external disruption as a system dependent on inputs made from non-renewable resources. One merely has substituted one source of vulnerability for another: for example, the source of the waste may close. This point has been made by Vail and Rozyne (1982), who found that "organic" farmers near poultry plants in Maine -- where the industry has been declining sharply -- did not take positive steps to build soil fertility, but merely exploited the fortuitous availability of poultry manure as long as they could get it, to save some money on fertilizer expenses.

The relation between sustainability and some versions of "low input" agriculture is also critical for understanding how important short-term economic factors have been in helping "sustainability" gain acceptance. I therefore take it up again in the next section.

Does sustainable agriculture require fundamental changes in either the economic and institutional environment or farmers' motivations and values?

This question provokes widespread disagreement. Some authors confine their discussions of sustainable agriculture to agronomic, environmental, and biological factors, or to economic evaluations under prevailing conditions. They believe that the same farmers, operating the same farms, can switch production systems without a significant change in attitude or in the economic, political and social setting in which farming occurs.

In other discussions, far-reaching socioeconomic transformations are emphasized even more than the technical differences between sustainable and conventional farming methods. These transformations include reduced linkage between farming and the industrial economy; more direct ties between producers and consumers; greater regional food self-sufficiency; a preference for family rather than corporate farms; policies that reward resource conservation; higher employment in agriculture; equitable distribution of economic returns among different classes of farmers and between present and future generations; and the social and economic revitalization of rural communities (Douglass, 1984; Crosson, 1986).

The connection, if any, between such transformations and changes in specific practices can go in either direction. That is, a different socioeconomic environment could be a prerequisite for widespread adoption of sustainable methods, or it could be a consequence of this adoption. For example, intensive use of chemical pest control is sometimes said by advocates of alternative agriculture to result from the domination of farming by agrichemical interests, who are described as exerting a strong influence on farmers' decisions and on research priorities. Therefore this domination must be reduced before farmers will be receptive to alternatives. On the other hand, if farmers decide to switch to reduced-chemical methods because they perceive problems with the particular agrichemicals now in use, such as high cost, fear of liability, or threats to their health, this switch will reduce the influence of the agrichemical industry. A desire to reduce that influence might not be why they made the change, but some people would consider the reduced influence to be desirable in its own right, apart from the undesirable properties of pesticides.

Another important structural issue that is still open concerns the most appropriate scale for sustainable agriculture. Its supporters often consider that it is most suited for small to moderate sized family farms. However, the empirical support for this view is largely lacking, and the theoretical arguments are equivocal (Buttel et al., 1986). Certainly, the trend towards larger farms has been associated historically with specialization, whereas sustainable agriculture favors diversification over specialization. Also, sustainable agriculture may require greater attention to management, as discussed below. If so, the farmer can give more attention to each field or each animal if the farm is not too large. On the other hand, larger farms may be better able to afford to hire specialized expertise, or to have better facilities and equipment.

The relation between the production system and the farmer's personal values is also unclear. Some authors see little connection. Today's farmers can, if they choose, adopt sustainable methods without any rethinking of motivations, values or broader philosophical considerations. Moreover, they will do so, it is argued, if the alternative is more attractive from the viewpoints of economic return or health and safety.

But to others, the reason a farmer farms is an overriding consideration. In

this view, farmers should be concerned not just with short-term profits, but also with the well-being of future generations, the rural communities in which they live and work, the natural environment, the esthetic appeal of the landscape, and the resources consumed in farming (Fischer, 1978; Bidwell, 1986). Such considerations are sometimes regarded as the distinguishing characteristic of sustainable agriculture (Freudenberger, 1986); the specific choices of production methods in turn follow from these goals.

As with the previous discussion of the institutional and economic environment, change can be started from either direction. If farmers can be persuaded to be more concerned about environmental values, they will adopt environmentally sounder methods. But if they can be persuaded to adopt these methods, for whatever reasons (for example, economics or more stringent environmental regulations), the result will be a system that in fact protects environmental values better, even if that is not why they chose to use it.

A possible objection to this last point is that changes made purely for economic reasons can be transient, given the variability of economic conditions. If farmers reduce pesticide use because crop prices have been too low to justify the cost, this environmentally beneficial change could be undone by the next sharp increase in crop prices, just as some good soil conservation work was undone by the exceptionally rapid price increases from 1972 to 1974, which led farmers to include even marginal land when planting "fencerow to fencerow" (Grant, 1975). The growing interest in "low input" agriculture has been closely tied to the distress in the farm economy during the mid 1980s. This points to a key difference between "low input" and "sustainable" approaches: even though both may have the short-term effect of reducing pesticide use, the latter does so for less ephemeral reasons than the temporary diseconomy of applying pesticides heavily when crop prices are low. The distinction between the two concepts is apparently eliminated by merging them under the singular term "lower input/sustainable agriculture." This term was proposed by Edwards (1987) as a solution to both overproduction and environmental problems. But trying to solve two problems for the price of one raises another question: what happens when the problem becomes scarcity, not surpluses? Must we give up sustainability when we need to produce more food?

Similarly, the term "low input/sustainable agriculture" has been adopted for a new program of research grants administered by the U.S. Department of Agriculture. It is not clear what is meant by joining the two components of this term. Are they to be regarded as equivalent, with one simply a different way of saying the other? Or is the composite term intended to cover any system that has at least one of the two characteristics? Or only those that have both (which may be only a subset of the previous category)?

It is difficult, but essential, to resolve the relationship between sustainability and the low input approaches adopted in direct response to current economic conditions. Although proponents of sustainable agriculture may prefer to emphasize longer-range considerations, short-range economic factors cannot be ignored: if a system doesn't return enough income to let the farmer remain in business, it isn't sustainable (Madden, 1987). The solution may lie in the earlier discussion of whether sustainable agriculture is primarily a matter of merely doing without certain materials, or of doing positive things that make these materials unnecessary. Ideally, with appropriate crop rotations, crop varieties, and tillage methods, the farmer who because of environmental reasons doesn't want to use pesticides won't have to and won't be tempted to even when crop prices rise again.

Does understanding sustainable agriculture involve concepts that are fundamentally different from conventional systems, or do we only need to extend the application of known principles to the conditions that prevail under sustainable practices?

The literature on sustainable agriculture offers various views regarding qualitative differences between the basic processes underlying sustainable and conventional production systems. One view is that both kinds of systems can be described and analyzed using the same concepts, and that they differ only in the specific conditions created by differing practices. Another view is that the complex interactions among the components of a sustainable farming system cause new phenomena to emerge that are not observed in the more simplified structure of a conventional system, so that one cannot understand the former by merely extrapolating from the latter.

Each of these views has some validity and the difference is often one of emphasis. An example is whether control of insect pests is fundamentally different in the two approaches. Sustainable control is generally described as using natural processes, such as predation or pests by other insects. Conventional control, in contrast, is sometimes represented as a "magical bullet" approach (Hill, 1982) depending entirely on insecticides, which not only substitute for natural processes, but may even interfere with them. For example, an insecticide may wipe out a beneficial species that previously had controlled a pest.

Where this does happen, pest control differs in a basic way between the two systems: in one it is a matter of toxicology, in the other an ecological phenomenon. No matter how much one studied the pest's mortality at different pesticide application rates, this knowledge would not be enough to predict the survival rate at zero application, where a different mechanism (predation) comes into play.

But sometimes the pesticide adds another control mechanism to the existing natural controls, rather than replacing them. If so, then the two approaches partially overlap. Even under "conventional" practice, many potential pests are actually controlled naturally -- without the farmer even having to do anything -- rather than by pesticides. Many elements of conventional pest control are the same as in sustainable practices, for example resistant varieties, good residue management, and best choice of planting date. Therefore it is not correct to describe sustainable and conventiona

practice as governed by fundamentally different principles and mechanisms -- "natural" as opposed to "chemical" -- despite the different relative importance of these mechanisms in the two approaches.

This question has important implications for agricultural research policy. Perhaps the established methods of agricultural research are appropriate for dealing with sustainable agriculture; all that might be needed is for more attention to be devoted to the particular techniques and particular conditions of sustainable agriculture. In contrast, some people believe that new approaches and methods are required, involving far-reaching differences in basic theories and concepts. The growing field of agroecology, as applied to sustainable agriculture, is an attempt to introduce new theoretical principles to analyze agricultural systems (new, that is, in the domain of agriculture, although well established regarding natural ecosystems). However, this field still is at a highly immature stage, and basic agroecological research is not yet receiving very strong support at most colleges of agriculture. Thus it has yet to demonstrate the potential that its supporters have claimed for it. In the meantime, a considerable portion of the work labelled as "sustainable agriculture research" differs from earlier kinds of research that it is supposed to be an improvement on mainly in that it generously uses terms like "systems approach."

To what extent do the resource-conserving and environmentally sounder techniques being developed at mainstream agricultural institutions already represent sustainable agriculture?

Two points discussed earlier -- whether acceptance of sustainable agriculture requires far-reaching economic or attitudinal changes, and whether understanding it involves a fundamentally different scientific outlook -- in turn raise the question of whether existing research and teaching institutions can deal with this area adequately. Long before the term "sustainable agriculture" came into common use, techniques with similar goals were already attracting attention. Examples include integrated pest management to reduce pesticide use, improved methods for storing and applying livestock manures to maximize their fertilizer value and reduce water pollution, and reduced tillage systems to control soil erosion. More recently, many agricultural institutions have started programs specifically labelled "sustainable agriculture." Such programs explicitly acknowledge the influence of the sustainable agriculture movement and indicate mainstream agriculture's interest in accommodating its ideas.

However, some people interested in sustainable agriculture -- both within mainstream institutions and on the outside -- do not view with undiluted optimism the changes that have already occurred in mainstream research, teaching, and extension. To some, the established research institutions are under very powerful constraints, especially the constraints imposed by disciplinary boundaries and by researchers' need to publish frequently. The latter in turn may discourage long-term projects, such as studies covering several cycles of a many-year rotation. These constraints may make it difficult or impossible for established institutions to organize agricultural research appropriately for dealing with sustainable systems (Bidwell, 1986). Also, to those who believe that sustainable agriculture involves fundamentally different principles, older ways of thinking are too firmly established among the current generation of researchers to permit newer ideas to flourish. Therefore, although such people may welcome the new interest in sustainable agriculture, they do not expect that the change will be able to go far enough in the current institutional environment. Buttel and Gillespie (1988) expect that the low-input work that mainstream research institutions are showing interest in will be done mainly by the same scientists -- now "born again" agronomists -- whose limited vision created the need for new approaches.

Some critics of current agricultural research believe that its limits are more fundamental and that they would not be eliminated even if appropriate institutional arrangements were provided and a new generation of researchers took over. This view considers the problem to be nothing less than the way scientists think about how the universe works. Our thinking, it is said, is too "mechanistic" or "reductionist" to encompass the complex relations of a sustainable agricultural system, a task for which a new scientific paradigm is needed (Cobb, 1984). However, this criticism may be making the mistake of attacking all science, rather than bad science. The most dramatic and exciting breakthroughs in the history of science include many that are profoundly "antireductionist": quantum mechanics, evolution, and general relativity, for example. To believe that one has a better way of understanding how the world works amounts to placing oneself above Bohr, Darwin, and Einstein.

Finally, certain critics -- again, this includes some individuals at mainstream agricultural institutions -- have argued that such institutions not only have failed to grasp the spirit of sustainable agriculture, but do not even want to. The flurry of recently instituted programs is said to be merely a way to appear to be responding to outside pressures, and perhaps also to blunt the full thrust of the movement. In this view, advancing the cause of sustainable agriculture means challenging some far-reaching economic, social, or political constraints, a challenge that mainstream agricultural institutions are not likely to mount (Altieri, 1988). Similarly, Buttel and Gillespie (1988) argue that because a range of concepts has been advanced under the name "ecological agriculture," mainstream agriculture has been able to choose the least-threatening version of it, sanitize it further to make it bureaucratically acceptable, and appropriate it as their own.

The relation between mainstream institutions and supporters of sustainable agriculture will undoubtedly clarify itself with time. The most discouraging outcome would be for the term "sustainable agriculture" to degenerate into just another bureaucratized buzz word used to show that something new and exciting is going on, even though noth-

ing has really changed. But perhaps the mainstream will prove highly receptive to the ideas now labelled as "alternative." If so, it might still be intrinsically advantageous to have someone whose role is to continue to challenge the established institutions and to keep prodding them to move further than institutional inertia would otherwise permit. On the other hand, if the receptiveness extends to the spirit of sustainable agriculture as a continuing quest, and not just to the specific details of systems being advocated today, then eventually it should be possible to drop the distinction between "alternative" and "conventional" as irrelevant and unnecessary.

Does sustainable agriculture require a higher level of management ability among farmers?

Sustainable agriculture is commonly said to require more management than conventional practice, both in how much effort the farmer must expend and in the quality demanded. The explanation is that sustainable practices substitute knowledge and understanding for technological control of growing conditions (Stinner and House, 1987). For example, in conventional practice, a disease of livestock might be completely controllable by routine prophylactic administration of an antibiotic, whereas in sustainable practice the goal is to prevent the disease by reducing stresses that make the animals more susceptible, and by housing them in conditions less conducive to communicating the disease. The farmer therefore must monitor the animals carefully to be able to start treatment promptly should it become necessary.

Another source of greater management requirements is said to be the need to make decisions on an integrated, whole-farm basis, in contrast to the more compartmentalized approach possible in conventional systems. Also, sustainable management is often depicted as the adaptation of general principles to the specific circumstances of the individual farm, whereas conventional practice is sometimes characterized as a "cookbook" approach -- a set of prescriptions that can be applied anywhere, without much understanding of the agroecosystem (Friend, 1983; Ehrenfeld, 1987). The sustainable agriculture literature emphasizes the need for flexibility and stresses that there is no one best method under all circumstances.

Although these arguments are persuasive, the question of comparative management requirements is still open. Certainly sustainable agriculture will require farmers to acquire different kinds of knowledge and skills, but this does not mean it is necessarily more difficult. Some proponents of sustainable agriculture may exaggerate the extent to which purchased inputs obviate the need for judgment in conventional practice, and may not take due account of the many decisions that still must be made even if one uses inorganic fertilizers, synthetic pesticides, and livestock antibiotics. For example, specialization, expansion, and heavy use of inputs in conventional approaches may require a *greater* management ability in handling financial and marketing affairs. Also, the stereotype of "cookbook" farming may indeed apply to poorer conventional managers, but not to the more discerning ones who still bring knowledge and experience to their operations despite the availability of chemical help. Also, some of the expertise required for sustainable practices can be hired, for example professional services for integrated pest management.

Finally, even if sustainable agriculture imposes greater management difficulties now, this problem may be reduced after farmers have had more experience with it and after more effort has been devoted to it by established research, extension, and teaching institutions. The lack of reliable information sources has been a common complaint among organic farmers (Wernick and Lockeretz, 1977; Baker and Smith, 1987), and undoubtedly applies to other sustainable approaches as well. Eventually, the mystique surrounding the complexities of sustainable management may disappear, and what now may seem bewilderingly complicated very likely can be made much more fathomable (Coleman, 1985). Farmers have been called on many times in the past to take on new management challenges, and it seems plausible that with appropriate support the challenges of sustainable management can be met as well.

Conclusion: Let's do it right

Sustainable agriculture is not so much a new idea as a synthesis of ideas originating from various sources, out of various motivations. It is continuously being modified and refined to reflect current economic pressures on farmers and the increasing concern over agriculturally related environmental problems. Although its roots go back much further, sustainable agriculture as an explicitly formulated concept is young compared to the time it will take to explore its ramifications and to understand fully its basic principles.

What can be done to advance this understanding? Certainly, more research and development are needed to apply sustainable agriculture concepts to specific situations and specific problems. However, unless we move considerably beyond merely doing some additional detailed empirical studies, it will amount to little more than a faddish but empty slogan. To fulfill its full potential, sustainable agriculture needs greater intellectual rigor. Important conceptual questions are not being asked, let alone answered. Fundamental principles still need to be developed and refined. Too much that needs to be demonstrated is instead simply asserted, or unconsciously assumed, or removed from debate by being made a matter of definition. People with a particular view of what sustainable agriculture is all about sometimes are not willing to acknowledge that other versions may be equally legitimate.

Supporters of sustainable agriculture often claim -- with considerable justification -- that mainstream agricultural thinking is too reluctant to challenge basic assumptions, too dogmatic, and too quick to become immersed in technical minutiae even though fundamental questions remain unaddressed. Ironically, sustainable agriculture runs the risk of repeating these mistakes. Fortunately, the field still has time to take heed of previous experiences. If it does

it will not only generate new solutions to the particular problems now affecting agriculture, but also set a new and better standard for thinking about agriculture in the future.

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Agronomy group defines "sustainable agriculture"

"Sustainable agriculture" means different things to different people. A group of 350 American Society of Agronomy members, meeting in late 1988 at the society's annual convention in Anaheim, California, hammered out their working definition. Here it is.

"A sustainable agriculture is one that, over the long term, 1) enhances environmental quality and the resource base on which agriculture depends, 2) provides for basic human food and fiber needs, 3) is economically viable, and 4) enhances the quality of life for farmers and society as a whole."

Family Farming: A New Economic Vision. 1988. Marty Strange. University of Nebraska Press, Lincoln, Nebraska, and Institute for Food and Development Policy, San Francisco, California. 311 pp. $18.95, cloth.

Few agricultural issues evoke as much passion, verbiage, or faulty reasoning as the condition of family farming. So much that has been written on the subject consists mainly of outworn catch phrases and half-truths, or conveniently overlooks data that refute one's most cherished prejudices. The level of discourse is all the more distressing considering the importance of our policy on family farming -- what politicians and agricultural leaders say it is, what it actually is, and what it should be. Consequently, the infrequent exception that rises above the pack is all the more welcome.

Family Farming is very welcome. Marty Strange tackles this difficult issue with fresh insights and sharp, well-supported arguments. On one hand, he is not the supposedly disinterested type who claims to be nothing but "realistic" when offering objective-looking analyses that "prove" that the family farm -- numerically still the most important kind -- is dead, or at least dying, a conclusion sometimes accompanied by an almost audible "good riddance." Nor is he the diehard agrarian fundamentalist who doesn't feel the need to offer any kind of supporting analysis in asserting that a system based on family farms can do no wrong, or in claiming that all kinds of societal ills or moral deterioration have resulted from our turning away from that system. In saying this, I don't want to pass over Strange's fundamental sympathy for family farming, a sympathy that he sets forth clearly at the outset. But in his own words, the sympathy is "not uncritical," and he has "never felt the need to apologize for [family farms'] shortcomings."

Rather than being interested mainly in passing out white and black hats, Strange attempts to explain how and why the structure of American agriculture has evolved in the past several decades, why this has lead to economic and environmental problems, and how its future development might be different. This task involves several intertwining arguments. The first is that family farming implies more than just who owns our farms and how large they are. It also involves certain ideals and principles, especially a sense of community with other farmers, and an economic structure in which the rewards go mainly to those who run the farm, rather than those who provide the capital. It follows that the family farm system erodes not only when corporate farms replace family-owned farms, but also when some family-owned farms expand at the expense of others, or shift to a management mode more characteristic of industry than of agriculture. Strange's third major point is that a farm's survival is not determined simply by its efficiency, but also by whether it has the financial resources to weather bad times. A farm often gets bigger not necessarily because it thereby becomes more efficient, but rather because it is able to pick up the pieces when another farm goes under. Technically speaking, such a farm may still be a family farm. But Strange offers a different criterion: Does the farmer feel more pain at the loss of a neighbor than joy at the opportunity to acquire the neighbor's land?

In developing these arguments, Strange convincingly challenges several dearly held bits of conventional wisdom. He questions the common division of farms into three size categories, of which the middle is supposedly disappearing because it is too small to be efficient but too large to allow for enough off-farm income. When the boundaries between the categories are chosen differently, a very different picture emerges: A category he labels "small commercial" constitutes a substantial segment of the nation's agriculture, one with financial resiliency, although a low income level. He also refutes the simplistic solution to family farmers' problems that consists of merely raising commodity price supports, arguing instead that this will only shift the rewards of farming further towards capital rather than labor and encourage cannibalization of some farms by others. A particularly striking point is that there is a great difference between preserving the family farming *system* and preserving family *farms*, that is, preserving those family farms that happen to exist at the moment. For example, reducing the inheritance tax on farmland will make it easier for farms to remain in the families that now own them. But it will also make it harder for future would-be farmers to acquire land, in direct conflict with the traditional egalitarian ideal of readily available farming opportunities. He cautions that by locking in current ownership, focussing just on preserving existing family farms risks creating a landed gentry.

The word "vision" is thrown around casually these days, but its use in this book's subtitle is fully justified. In contrast to those who merely try to tinker with our basic farm policies, Strange offers a set of simple but far-reaching fundamental principles to guide the farm policy of the future: That a farmer should be able to pay for farmland by farming it well; that the farmer should have to farm it well; that the farmer should have to pay for land by farming it, and by no other means; and that there should be no motive for owning farmland other than to make a living by farming it well.

But in contrast to other "visions," this book is also based on solid "on-the-ground" experience in working with real farmers, and on a realistic understanding of our political and economic system. Unlike some authors on this topic, Strange avoids setting forth

a "vision" based purely on his own personal values, values that implicitly are better or more noble than those that farmers are thought to hold. Rather, his premise is that farmers really want to uphold the values of the family farm system, and that if their actions sometimes seem to have conflicted with these values, in part this was because they had no choice, or more precisely, that they believed they had no choice.

That his alternative vision for American farming is not hopelessly optimistic is supported by the record of his own institution, the Center for Rural Affairs, Walthill, Nebraska, of which he is a founding co-director. The Center has achieved impressive results in helping farmers develop and adopt resource-conserving, low-cost production methods that enable them to bolster their income without expanding excessively rapidly and without going dangerously in debt. Strange and his colleagues have also shown that much of the movement away from a family farm system towards a more industrial, capital-intensive model has been motivated not by true efficiencies, but by government policies that distort the comparative advantages of different kinds of farms. Particularly good examples are the tax laws that favor large-scale hog confinement facilities and center pivot irrigation. In analyzing these issues, the Center has never hidden its preference for a particular kind of agriculture and its desire for far-reaching changes. But unlike some activist organizations, it does not take a public stand without first doing its homework.

This book draws heavily on this experience, and reflects the virtues that have earned the Center considerable respect, however begrudgingly bestowed, even among those on the opposite side of an issue. It is written in clear, forceful language that avoids unnecessary jargon. It is well-organized, and although its arguments are not simple, they no doubt will be easily followed even by someone with little background in American agriculture. Most important, it offers a generous helping of both pragmatism and vision, and presents well-reasoned arguments against some myths that are taking a long time to die. I expect that at the very least it will be among the few popularly oriented books on farm policy still considered well worth reading more than a year or two after publication, and I would not be surprised if it comes to be regarded as a genuine classic. -- *William Lockeretz, Research Associate Professor, School of Nutrition, Tufts University, Medford, MA.*

FROM THE LITERATURE

Abstracted by William Lockeretz

Research reports

Long-term effects of quality-compost treatment on soil. A. Marchesini, L. Allievi, E. Comotti, and A. Ferrari. *Plant and Soil* 106:253-261 (1988).

This study examined the effects of compost application on soil chemistry, soil microflora, and crop yield. The experimental material was compost produced from refuse from the vegetable market in Turin, Italy, and from paunch manure, mixed approximately in the ratio 9:1. The authors consider this to be "quality compost" compared to more commonly studied materials, such as composted sewage sludge or composted urban refuse. The five-month composting process had two stages: a rotary digester, followed by covered piles that were turned periodically. The compost was applied six months later.

All treatments were done once, at the start of the five-year study period. Compost was mixed with soil at levels corresponding to 10, 20, and 30 metric tons/ha, with NPK fertilizer added to make the total nutrient applications equal. Other treatments were NPK fertilizer only; 95 percent compost mixed with 5 percent soil (this treatment involved a different nutrient application level); and an untreated control. Two crops of corn, followed by two quick crops of chicory, were grown in pots in the first two years (data not reported). The paper reports on three subsequent crops of sunflower, with soil analyses performed at the end of the fifth year. Sunflower was chosen because it is a heavy feeder and therefore was suitable for investigating nutrient drawdown over the five-year study period. Since it is a livestock forage in Italy, both seed yield and whole-plant dry matter production were measured.

Total dry matter increased noticeably with increasing additions of organic matter, but seed yield varied only slightly. Total dry matter decreased from the third to fifth year with most treatments. Yield with NPK was comparable to the 10 ton/ha treatment in Year 3, but declined more rapidly. By Year 5, the NPK treatment no longer caused a yield increase.

Soil organic matter, total N, assimilable P and assimilable K were much higher with the 95 percent compost mixture, but varied little among the other treatments. This treatment also showed the highest levels of several groups of microorganisms, including total aerobic bacteria, total anaerobic bacteria, fungi, anaerobic N-fixing bacteria, denitrifiers, and anaerobic cellulolytic bacteria. All these groups mineralize organic matter, which was higher under this treatment. In contrast, nitrifying bacteria, which oxidize ammonium, were lowest in the 95 percent compost treatment. There were few strong differences among the three other compost treatments and NPK. The authors conclude that the usefulness of compost in crop production is not so much a result of immediate nutrient availability but rather its long-term beneficial effects on the soil conditions affecting fertility and productivity, perhaps through qualitative changes in the soil's microflora.

Prodigal Crops: A Review of Proposals for Sustainable Agriculture, from the Midwestern Legislative Conference, gives a list of state-level actions that could encourage sustainable agriculture. The actions include incentives for local processing of farm products, creating standards for organic foods, creating special programs on sustainable agriculture at land grant colleges, funding farmer meetings to spread information, and taxing farm chemicals to discourage their use. The report also lists states which currently have policies supportive of the move to a more sustainable agriculture. For information on the report, contact David Ensign, The Council of State Governments, 641 E Butterfield Road, Suite 401, Lombard, IL 60148.

Farming and Groundwater: An Introduction is a clear, well-illustrated assessment of the current relationship between farm chemicals and water quality from the Agricultural Law and Policy Institute.

In assessing the sources of groundwater contamination by farm chemicals, the report notes that the most intensive and damaging use of these chemicals is associated with grains grown for animal feeds - also our chief export crops. "If the result of increased export sales is diminished groundwater quality, we must question whether the price is worth paying," the report says.

For information contact the Agricultural Law and Policy Institute, the University of Minnesota Law School, 285 Law Center, 229 - 19th Avenue South, Minneapolis, MN 55455.

The Pesticide Crisis: A Blueprint for State Action provides models for action in areas such as state registration and the farm, forest, and residential use of pesticides. Jim Hightower, Texas Commissioner of Agriculture, gives the introduction. The book is $12 from the National Center for Policy Alternatives, 2000 Florida Avenue, NW, Washington, DC 20009.

Gross Margin Analysis, a computer-based program designed for management of diversified vegetable, fruit, or cash crop businesses, has been developed by Extension specialists at Michigan State University. The program estimates income, variable expenses, fixed costs, and revenue break-even points, along with other data. It is designed to run on an IBM compatible computer with MS-DOS 2.0 and 360K storage capacity and is particularly useful in diversified farming situations to help determine the profitability of various crop enterprises, its authors say. The software and manual are $25 from Software Distribution Center, MSU Cooperative Extension Service, P.O. Box 6640, East Lansing, MI 48826-6640.

Sustainable Agriculture, a newsletter from the Sustainable Agriculture Interest Group at Ohio State University, has short articles by faculty members, lists of meetings, publications, and research.

To get on the mailing list, contact Nancy Creamer, Entomology Department, OSU, 1735 Neil Avenue, Columbus, OH 43210.

Environmental Effects of Conventional and Organic/Biological Farming Systems, by C. Arden Clarke, is a comprehensive review of the international literature comparing conventional and organic farming systems. Four major areas are covered: soil structure and erosion; soil ecology, fertility, and nutrient cycles; pest control strategies and impacts on crop ecosystems; and farming system impacts on wildlife habitat. Although conclusions are stated tentatively, the report finds plausible grounds for believing that organic systems are preferable with regard to all four areas covered. The 250+ page report is available from The Political Ecology Research Group, 34 Cowley Road, Oxford OX4 1HZ, England. The price in the U.S. (2 vols.) is $56.50 air; $50.00 surface.

Choices for the Heartland is a report on desirable goals for agricultural biotechnology from the Center for Rural Affairs in Nebraska. New biotechnologies are rapidly increasing the power of scientists to "reshape the plants, animals, insects, and microorganisms used in agriculture," the report says. Such research should be directed toward enhancing low-input sustainable family farm systems rather than supporting "industrial agriculture," it argues. The report is $6 from the Center for Rural Affairs, P.O. Box 405, Walthill, NE 68067.

Troubled Waters--Troubled Lands, a primer on the social impacts of water policies in the Central Valley of California, calls for support of environmentally sound family farms instead of large operations. The 16-page booklet is $2 from the California Institute for Rural Studies, P.O. Box 530, Davis, CA 95617.

Farming with Fewer Chemicals is a directory of over 40 Iowa farmers and their operations, with specific details on the use of fertilizers, rotations, manure, and pesticides. For information contact Iowa Citizens for Community Improvement, 1607 E Grand Avenue, Des Moines, IA 50316.

Integrated Farm Management Notes, a newsletter from the Iowa Integrated Farm Management Demonstration Project, describes the goals and work of that program. Demonstrations have been developed in nearly every county in Iowa, the November 1988 issue says. For information contact Extension Communications, 103 Morrill Hall, Iowa State University, Ames, IA 50011.

Managing Irrigation with Gypsum Blocks is a step-by-step guide for farmers to this water- and cost-conserving method of monitoring changes in soil-moisture levels in crop-root zones. The 30-page booklet is $10 from Inform, 381 Park Avenue South, New York, NY 10016.

IAA symposium outlines components, needs of sustainable farming

Sustainable farming systems involve "physical, economic, institutional, and social components," keynote speaker Dennis Keeney, Director of Iowa's Leopold Center for Sustainable Agriculture, told the February 28 IAA symposium in Washington, DC. Crop rotations and integration of livestock are essential elements to consider, but off-season work for farm families, new roles for farm industry, and wildlife habitat are also components.

Describing a sustainable system in practice, North Dakota organic farmer Fred Kirschenmann told the audience that crop rotations had helped his soils build drought resistance. "Our 1988 rainfall was just over one inch," he said, "but our wheat crop was 80 percent of normal."

Commodity programs tend to push farmers into production of the "big four" crops--wheat, corn, cotton, and soybeans, Douglas Young of Washington State University told the symposium audience. Those crops also receive a majority of agrichemicals, with corn alone receiving 51 percent of all herbicides. Projecting the consequences of a "less distorted" commodity program, John E. Lee of the USDA Economic Research Service speculated that "the people who'll be squeezed out [of farming] are those who are doing the most damage to the environment."

In the final panel, Ken Cook of the Conservation Foundation suggested that waste of nutrients and soil on farms leads to pollution but also points to "inefficient use of inputs." The 1990 farm bill "could establish goals for farm waste reduction," he said.

Note: The symposium proceedings will be published in a forthcoming issue of the American Journal of Alternative Agriculture.

IAA Board elects Jean Douglas President, seats new members

Mrs. Jean Wallace Douglas, a long-standing supporter of resource-conserving, environmentally sound farming systems, was elected President of the Institute's Board of Directors at its March 1 meeting in Washington, DC. Mrs. Douglas has been a member of the IAA Board since 1984. Jay Harris of Berwyn, Pennsylvania, was re-elected Vice President. Jerry DeWitt, Associate Director, Cooperative Extension Service, Iowa State University, Ames, was elected Secretary; and Maureen Hinkle of the National Audubon Society was re-elected Treasurer. New Directors William Liebhardt, of the University of California-Davis, Jim Bender, farmer from Weeping Water, Nebraska, Per Bye Ohrstrom, owner of two Illinois organic product companies, and Gordon Watkins, owner of the Rivendell Gardens in Arkansas, were officially seated at the meeting.

The Board decided that innovative methods for moving sustainable farming information would be the topic for the Spring 1990 IAA symposium.

IAA participated in national low-input meeting

The March 8-10 Soil and Water Conservation Society meeting in Omaha on "The Promise of Low-Input Agriculture," co-sponsored by the Institute, provided an overview of low-input issues nationally. Keynote speaker Neill Schaller, Program Director of the USDA LISA program, commented that low-input sustainability is a "way of thinking, not a specific method," and pointed to the multiplicity of ideas involved.

The Soil and Water Conservation Society will publish a special issue on "The Promise of Low-Input Agriculture" in its November/December 1989 issue. Submissions of papers are welcome until August 31, 1989. Contact the Editor, *Journal of Soil and Water Conservation*, 7515 Northeast Ankeny Road, Ankeny, IA 50021-9764.

National organic/ sustainable agriculture conference

The March 16-17 national conference on organic and sustainable agriculture, sponsored by the Center for Science in the Public Interest and co-sponsored by the Institute, brought participants from every aspect of the food system together in Washington to consider the status and needs of organic farm and food systems. Panel discussions covered research and information, marketing, organic certification programs, financing for alternative ventures, and national policy needs.

IAA active in working group to support LISA funding in FY1990

The Institute is actively supporting continued funding for the USDA low-input sustainable agriculture program (LISA) in FY1990. Staff will provide testimony to both Senate and House appropriations committees and work cooperatively with a Washington-based coalition formed to gain that funding. The Administration budget for FY1990 does not include the program, although LISA has had strong support from researchers, educators, farmers, and both the public and private sector groups involved. In 1988, Congress overrode the Administration zero-budget and provided $4.45 million for the program.

IFOAM conference focuses on agricultural alternatives and nutritional self-sufficiency for developing countries

The seventh scientific conference of the International Federation of Organic Agriculture Movements (IFOAM) was held January 2-5, 1989, in Ouagadougou, Burkina Faso, a small country located in the arid and semiarid tropics of the sub-Saharan Region of West Africa. IFOAM has become the largest and best known international organization in the field of organic/sustainable agriculture with members from more than 50 countries. This is the first time that the annual IFOAM conference has been held in a developing country. Earlier conferences, the first of which was held in 1977, had alternated between Western Europe and North America.

The conference theme, "Agricultural Alternatives and Nutritional Self-Sufficiency," was particularly appropriate in view of the focus on developing countries, especially those that comprise the sub-Saharan Region of Africa. In some of these countries food grain production per capita has declined, alarmingly so, during the past decade. The conference emphasized that much of this can be attributed to improper or inadequate soil, water and crop/livestock management practices which have caused extensive degradation of the natural resource base, i.e., agricultural lands, from soil erosion and desertification, and the consequent loss of soil productivity. The conference also emphasized the need to improve the nutritional quality of crops in both developed and developing countries.

The seventh IFOAM conference was the largest so far, with more than 600 participants from 48 countries, mainly from Europe and Africa. Some 90 technical papers were presented covering a broad range of topics. The conference was especially important to the African participants who face such monumental problems in restoring and improving the productivity of their often fragile agricultural lands and who are seeking low-input and limited-resource alternatives on how to accomplish this. Also, this was evidenced by the warm reception and excellent hospitality by the government of Burkina Faso and the attendance of their President, His Excellency Blaise Compaore, at the opening ceremonies. The conference was organized by Dr. Pierre Ott and Dr. Denis Lairon, IFOAM representatives from France, with the assistance of others from Germany and Burkina Faso. It was sponsored by several Pan-African and international organizations.

Prior to the conference there were four separate field trips between December 28-31, 1988. About 180 people attended the field trips, with the trip to the Sahel area being the most popular. This trip illustrated the agroecological activities and soil conservation programs in an area that is experiencing severe desertification. The other trips included visits to the Plateau Mossi in the vicinity of Ouagadougou with its "Green Belt" and market gardeners and to the Southwest with its fruit and vegetable growing area. Field trip participants were received most hospitably by the local villagers and government representatives.

The format of the conference was one-half scientific and technical presentations (morning sessions) and one-half panel discussions and papers (afternoon sessions). About two-thirds of the scientific and panel papers were on agricultural issues which confront developing countries. The sessions dealt with a number of different themes including: human resources and agricultural development programs, ecological improvements of agricultural techniques, soil biology, organic farming systems, water preservation and desertification, agroecosystems, nutrition and the environment, preservation and quality of agricultural produce, pest control and organic fertilization, networking for ecodevelopment, green manures and agroforestry, and strategies for alternative agriculture. In addition, there were numerous poster displays on research, development, and educational projects in different countries.

The seventh IFOAM conference was a highly successful event as demonstrated by the number of attendees, their diversity of interests, and the high quality of papers presented. This conference clearly reflected the increasing interest worldwide in organic agriculture and a rather strong consensus that we need to develop viable alternatives and strategies for sustainability.

The eighth IFOAM conference will be held in Budapest, Hungary, in May, 1990. For more information on IFOAM membership and its future program plans, conferences, and publications, write: IFOAM General Secretariat, Ecocentre Imsbach, D-6695 THOLEY-THELEY, Federal Republic of Germany (Tel: 49/68 535 190).

John P. Reganold, Assistant Professor, Department of Agronomy and Soils, Washington State University, Pullman, Washington; and James F. Parr, National Program Staff, USDA-ARS, Beltsville, Maryland

Britons discuss "The Case for Organic Agriculture"

A three-day conference reviewing the status of organic agriculture drew about 300 farmers, agricultural advisors, and representatives of food-related industries to the Royal College of Agriculture in Cirencester, England, in January, 1989. The event was the sixth in a biennial series sponsored by Britain's two leading organic producer organizations, the Organic Growers Association, and the British Organic Farmers. The Elm Farm Research Centre, a privately supported, non-profit institution for research and extension, also played a major organizing role. The conference received national media attention, in part because of a warmly supportive message from Prince Charles.

The plenary program covered three major areas: government programs on behalf of organic agriculture in several countries; organic food certification and other marketing issues; and the relationships between organic farming and other movements. Parallel workshops dealt with technical aspects of production and marketing.

The speakers were primarily from Britain, but an international perspective was provided by presentations from Sweden and Denmark. In addition, I gave the final speech of the conference, on the theme "Organic Farming: Its Role in the Agriculture of an Industrial Society," as well as a talk on the alternative agriculture situation in the U.S.

The conference showed that standards for certifying organic products are well-established in Britain. The Soil Association, an organization with which the conference organizers work closely, has developed a detailed set of standards that have been well-accepted by producers, the food industry, and consumers. An advisory committee is developing certification standards for the government, which at the time of the conference were expected to be similar to those of the Soil Association. If so, the combination of private monitoring and government enforcement would further insure their integrity and acceptance.

Particularly interesting were the discussions between organic farming supporters and speakers from several other organizations who were invited specifically to allow relations among the various interests to be thrashed out. These speakers represented food consumers, the environmental movement in general, and the wildlife protection movement in particular. The conference organizers realized that, although the goals of these groups and of organic farmers should be mutually reinforcing, there are tensions that stand in the way of cooperation. For example, organic farming supporters consider their emphasis on nutritious and wholesome food to be in consumers' interests, but a speaker from the London Food Commission noted that this food currently is more expensive, which works against the nutritional well-being of lower-income consumers. The speaker from Friends of the Earth seemed to regard organic farming mainly as a way for producers to capture a specialized, high-price niche market, rather than as a way to ameliorate agriculture's environmental problems; therefore he was much more interested in "low-input" agriculture. Finally, a representative of the Royal Society for the Protection of Birds emphasized that areas should be left for wildlife habitat and implied that organic farming by itself did not meet this need.

The organic farming supporters had persuasive answers to all these points. They argued that farmers did not choose organic methods to be able to get a premium, but rather that the premium enables them to choose a farming system they prefer because it is more environmentally desirable; depending on how the European Economic Community revises its subsidy and support programs (which clearly will happen soon, although in what way is unknown), this premium might no longer be necessary. They also argued that support for "low-input" agriculture takes away from organic farming's chances to prove that it deserves a major role in the agricultural system, and instead restricts it to its current marginal position. In addition, the methods required under the Soil Association's standards will make the farm more attractive to birds on the active farmland, not just on whatever areas are dedicated to bird habitat. Although the speaker from the bird protection group favored set-asides (a new concept for Britain) as a way to provide habitat, the organic farming advocates noted that set-asides encourage intensification on the remaining land, thereby destroying more habitat than they create.

In assessing the status of organic agriculture in Britain, the conference organizers could list both discouraging and encouraging developments. The number of organic farmers is still very low, and research attention is inadequate. But British consumers are increasingly interested in more wholesome products, the public's support for environmental protection is strong, and farmers and taxpayers alike recognize that current farm programs are not serving the interests of either of them.

One encouraging factor that I, as an outsider, am free to add to this list is that the level of discourse at this conference was very high. I was impressed by the well thought-out and intelligently presented talks and discussions. Clearly, many organic farming supporters in Britain care not only about its technical aspects, but also about why they do what they do, how it affects everyone else, and how it can be made to serve broader social goals even more effectively. This alone leads me to feel that, even though numerically the movement is still weak, it has a vitality and a fundamental soundness that will increase its influence in the future.

William Lockeretz, Research Associate Professor, School of Nutrition, Tufts University, Medford, Massachusetts

New department: Alternative agriculture profiles

A note from the editor

Beginning with the next issue, the **American Journal of Alternative Agriculture** will accept short write-ups about farmers who have adopted interesting alternative practices that conserve resources, protect the environment, or cut production costs by reducing purchased inputs. We invite you to submit articles for this department.

This could be a particularly appropriate medium for those of you who, in your research on alternative systems, have collected more information about individual farmers than you could present in your research reports. We particularly welcome articles about alternatives that are not widely known or that have broad potential applicability. Success stories make the most enjoyable reading, of course, but unsatisfactory experiences can be very informative, too, especially if accompanied by an insightful analysis of why things went wrong.

Here are some guidelines regarding what to include:

1. A brief description of the farm, e.g., its physical resources, its people, its history, its major enterprises, and its marketing system, if there is anything unusual about it. This should be presented mainly in tabular form, with supplementary text as needed. Emphasize those facts about the farm that are particularly relevant to its having switched to an alternative system.

2. The problems that made the farmer look for an alternative approach and the reasons that the alternative eventually adopted seemed like a plausible solution.

3. A summary of the basic principles behind the alternative. If this requires more than a few sentences, you can instead refer to a good, readily available review article. If there is none, you can present this material as a sidebar so that it doesn't interrupt the flow of the narrative. You might include a photograph or diagram, but only if one is needed to illustrate a piece of equipment or technique that is probably unfamiliar to most readers.

4. A discussion of how well the alternative has worked, the remaining problems, and the future changes, if any, that the farmer expects to carry out. Has the system worked as well as hoped, not as good, or better? Has the farmer modified the original plan based on early experience? Preferably, this section should be supported by some objective, quantitative data. If this is not possible, however, a reasonable, informed judgment will suffice. Please make clear, however, the extent to which this section is based on hard data, anecdote, or casual observation, and who is making the judgment.

5. A discussion of the applicability of the alternative to other farmers. Were there special characteristics of this farm that made this alternative particularly suitable? What kinds of farms would it probably work best on (e.g., particular size, kind of soil, access to markets, available labor, etc.)? For whom is it clearly not suited?

Although these guidelines cover a large amount of material, the article should be brief - typically 1500 to 2000 words. It should not strive to offer a comprehensive treatment of a particular alternative; that is the function of research reports and review articles. Rather, it is supposed to show how an alternative system has actually worked out in one concrete, real-world case. Therefore, the article should strike a balance between the details of the particular farm on one hand, and on the other the broader ideas that the farm embodies, and that other farms might incorporate as well.

Finally, one legalistic detail. Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the **American Journal of Alternative Agriculture**.

We think that this department will add an intriguing and informative dimension to our coverage of alternative agricultural systems, and we look forward to seeing your contributions.

LETTERS TO THE EDITOR INVITED

The AJAA welcomes letters, short or long, commenting on articles in this journal or sharing ideas likely to be of interest to other AJAA readers. Since our space is limited, we do reserve the right not to publish all letters or, at times, to publish only excerpts from them. To take part in this exchange of ideas, write to: Editor, AJAA, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770.

Guide for authors

AJAA will publish original research on biological, physical, or social science aspects of alternative agriculture. We particularly welcome multi-disciplinary studies, but papers from a specific discipline also are invited. However, since AJAA readership is much broader than for a single-discipline journal, highly specialized terminology should be explained or avoided. The significance of a statement, or the reasoning behind a conclusion, may have to be spelled out more than in a more specialized journal. Research papers usually should be no longer than about 20 double-spaced pages.

Nomenclature and technical details

Research papers should use the International (SI, or metric) system throughout. Write out "liters". "Metric ton", although not strictly an accepted SI unit, can be used for data referring to "ordinary life," such as national crop output, as opposed to experimental data. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

The binominal or trinominal designation of a plant or animal species, and the cultivar where relevant, should be given in parentheses the first time the common name of the species is mentioned. Either name may be used thereafter. The same applies to names of chemicals that have both a common name and a chemical name. Do not use brand names except where the chemical is produced under a unique brand name. In those cases the brand name, identified as such, may be given the first time the chemical is mentioned. Nutrient applications should be given in elemental form (N,P,K). Oxide forms can be used in describing commercial fertilizers.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

Abstract

The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

Reference list

References should be listed in alphabetical order by author's name, and by year for a particular author (with letters after the year if needed). If a sole author is also the lead author of papers with multiple authors, use the following order: single author (by year); two authors (alphabetically by second author's name); three or more authors (by year). Repeat the author's name for each reference. Use initials only for first and middle names. Give the names of all authors in the reference; never use "et al."

Use full names of journals, institutions, conferences, etc., except for extremely familiar abbreviations like "Dept." Remember that an abbreviation familiar to you may not be familiar to readers outside your field. If in doubt, write it out.

The reference list uses no quotation marks, italics, boldface, or underlining. Only the names of books and periodicals are in initial capitals. Names of papers, book chapters, pamphlets, and bulletins are not capitalized. Page numbers are written out in full (e.g., 1108-1123, not 1108-23). The volume is given if page numbers begin at 1 for each issue.

Citing references

Cite references in the text by last name and year, with chapter or page numbers if the reference is a book or lengthy report. For two authors, give both names. Do not use "et al." unless there are at least three authors.

Footnotes

AJAA does not use bibliographic or substantive footnotes. All bibliographic references should be at the end of the text. Instead of substantive footnotes, include the material in the main text or consider eliminating it.

Manuscript preparation

The entire manuscript, including abstract and references, should be typed on one side of standard-size paper, double spaced, with margins of at least one inch all around. Starting with the title page, label all pages in the upper righthand corner with the lead author's last name and the page number. Do not use hyphens unless the hyphen is part of the word. Do not underline anything except species names.

Follow the section headings style used in this AJAA issue. All headings are flush left, with no underlining or italics.

Tables should fit on one page, be numbered consecutively with Arabic numerals, and be on a separate sheet. Leave extra space to separate columns. Every figure and table should be mentioned at least once in the text.

Submission of manuscripts

Submit four high-quality copies to Editor, American Journal of Alternative Agriculture, Suite 117, 9200 Edmonston Road, Greenbelt, MD 20770. The cover letter should state that the manuscript is an original contribution that has not been published elsewhere in substantially the same form; that it is not currently under consideration elsewhere, and that permission has been obtained for any copyrighted material used.

How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization set up in 1983 to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

If you're interested in helping us, please contact our office at 9200 Edmonston Road, Greenbelt, MD 20770. The phone number is (301) 441-8777.

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ALTERNATIVE AGRICULTURE, INC.